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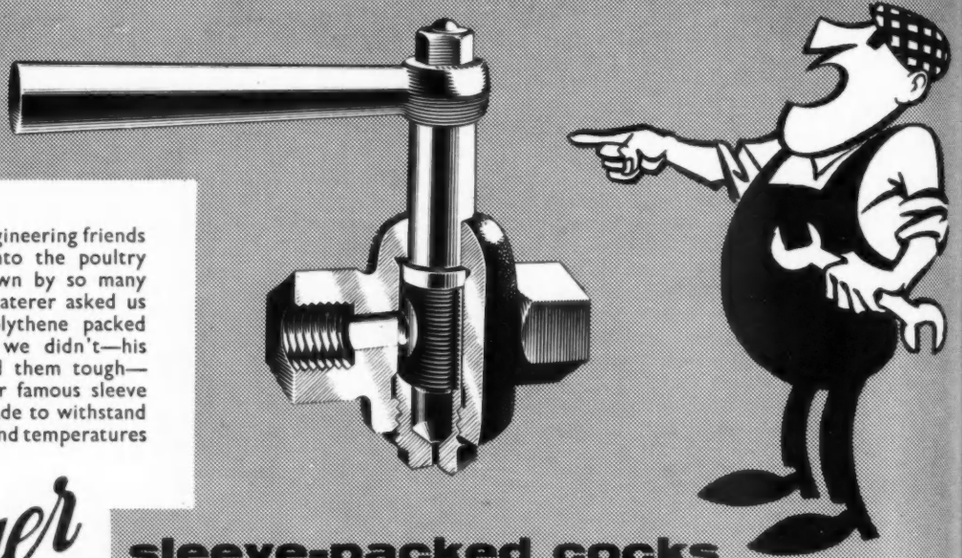

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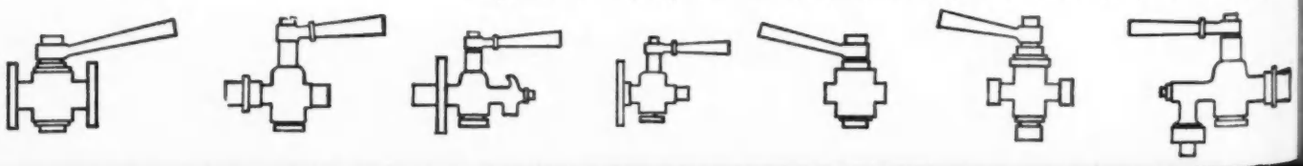

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THE ENGINEER

No. 5505 JULY 28, 1961 Vol. 212

PAUSE FOR PRODUCTIVITY?

As we were going to press with this week's issue the Chancellor's "little budget" was announced. Some time will be needed to assimilate all the details and to evaluate them properly but the main outlines of the Chancellor's statement stand out sufficiently clearly to warrant comment. We do not quarrel seriously with the diagnosis of Britain's economic malady. The basic fact is that for many years past this country's wages and other incomes have been rising much more rapidly than her total production. The resulting deficit, repeated year by year, is obviously incompatible with a viable economy and the danger of the situation is accentuated by the keen competition now being offered by other industrial countries, particularly in Europe. As this competition grows so Britain runs an increasing risk of being priced out of her export markets and of being forced to accept a diminishing standard of living.

What remedies has the Chancellor proposed? First, as a short-term measure, there is the familiar and crude process of diverting attention to exports by throttling demand at home. To engineers there seems to be something inherently clumsy about this inverted way of stimulating exports; we should have preferred to see some more positive and direct incentives offered to exporters. Perhaps they will come later. For the present the philosophy—expressed in terms of an inexact but homely analogy—seems to be that a sharp dig in the ribs is the quickest, if not the best way of urging the horse to increased efforts. In stating the problem of rising costs and prices the Chancellor is on firm ground when he says that there must be a pause in incomes until productivity has caught up and there is room for further advances. "A pause must mark the beginning of a new long-term policy . . . that increases in incomes must follow and not precede or outstrip increases in national productivity." The policy, easily stated, will certainly be difficult to implement. After years of a tacitly accepted "free-for-all" in wage claims it will not be easy to persuade the trade unions to accept a "pause". It will be helpful if the unions can be convinced that the "pause", voluntary or compulsory, will apply equally to all incomes, including those from dividends and, particularly, from speculative sources. In short the Government may have to be tough but it will have a better chance of succeeding if the toughness is seen to be applied equitably.

STRUCTURAL CHANGES IN THE I.E.E.

For about two-and-a-half years the Council of the Institution of Electrical Engineers has been considering changes in its structural organisation which might better enable it to discharge its functions as a learned society. Most of the scientific work of the Institution has been carried out, for many years, through the medium of various specialised sections, which now number four—"Electronics and Communications", "Measurement and Control", "Supply" and "Utilization." Recently it has become apparent that this system of specialised sections, which has served the I.E.E. well enough in the past, is too rigid to keep pace with the rapid development that is taking place in many branches of electrical engineering, particularly electronics. Frequently, there have been excessive delays between the emergence of a new technical development and its effective coverage by the Institution. In addition the Council feels that it has become "difficult to demonstrate the high proportion of electronics activity within the Institution".

To remove these general disabilities the Council has approved a proposal to replace the existing four specialised sections by three elected "Divisions", two of which would represent "electronics" and "power" interests respectively while the third, a "general" division, would be concerned with other matters (such as technological education and the fundamentals of measurements) which are of common interest to all electrical engineers. The activities of each of the new divisions would be guided by an elected "Board" and implemented through the medium of several "Technical Group Committees" to serve the specialised interests which, taken together, cover the whole field of electrical science and engineering. Inherent in these proposals is the important provision that the Technical Groups should be capable of being formed or re-formed rapidly to meet changing needs without delay.

Under the proposed scheme the government of the Institution would, of course, "remain vested wholly in the Council, advised, as at present, by the standing committees". However, the Divisional Boards would be able to participate in the formulation of policy because they would have strong representation on the Council and on the standing committees. Local centres would organise their specialised groups to suit their individual needs. Indeed the proposals as a whole would involve a good measure of decentralisation, with considerable devolution of responsibility for special interests. In an Institution of the size and status that the I.E.E. enjoys, this diffusion of responsibility should be wholly beneficial.

RURAL ELECTRIFICATION

Two reports were published last week on an investigation carried out at four demonstration farms in the West Country into the effect of electricity on farming. The reports were published by Bristol University's Department of Agricultural Economics, and by the South Western Electricity Board, the project being approved by the Electricity Supply Industry's Utilisation Research Council which provided a grant for the investigation. The S.W. Board is to be congratulated on the lead it has taken and the initiative it has shown in this particular instance, for as it points out in its report "Rural electrification is a costly process and relatively unremunerative to Electricity Boards."

Farms were selected which offered a prospect of several applications of electricity, and where the farmers

were willing, on extended terms for capital expenditure, to install and use equipment as advised by the Board and to keep records of its use. They also provided information and facilities for study of certain aspects of their farming prior to electrification. The author of the University's report, Mr. V. Baker, watched the progress of the scheme from the start so that it was possible to produce at the end an unbiased account of what happened and what it meant. The very detailed report which resulted, "Electricity and the Farm Business," gives direct comparisons of running costs and labour needs before and after electrification, and assesses the overall effect on farm profitability of using electrical equipment. But as the report points out, for the purpose of weighing up the impact of electrification on the farm business and considering it in relation to the economy of the farm, although the direct procedure would seem to be to analyse the actual farm accounts before and after the introduction of the Board's electricity, in practice such a process might be misleading and unsuitable. A farm financial result varies from year to year with changes in policy, rotation and prices to an extent that would smother the modest effects the report tries to assess.

We were able to inspect Charmeydown Farm, near Bath, which was one of the four farms concerned in the Board's investigations, and there we noted that before being connected to the electricity mains in September, 1958, the farmer had generated his own electricity by means of a 230V, 3kVA diesel alternator, using about 3890 units in twelve months at a total cost of 6·5 pence per unit. In the last four quarters, he has used 30,102 units of the Board's electricity at a total cost of 1·26 pence per unit. Amongst the new equipment installed at Charmeydown is a new combined water heater and steam raiser, and the cost of heating some 8400 gallons of water and also producing the steam required for sterilising has worked out at 1·7 pence per gallon. Before being connected to the electricity mains, hot water and steam were produced from a coal-burning boiler, the cost of which for some 3800 gallons has been estimated at 4·6 pence per gallon. Raising steam in the old boiler at Charmeydown took approximately 150 hours per annum. No hot water was available for the start of the morning milking under this delayed system of water heating and since the fire was out in the afternoon there was none for the afternoon milking: what was required was carried from the house. Thus, apart from cheaper hot water the introduction of electricity has also effected a considerable saving in man-hours. The Board has estimated that the saving in labour brought about by the changeover at the four farms averages 485 hours per farm a year.

Since the electricity supply in England and Wales was nationalised in 1948 about 150,000 farms have been joined to the electricity mains and some £50,000,000 have been spent on the distribution system alone. During 1960-61 an average of twenty-nine farms were connected every day. As a result of the considerable speeding up of the rate of extending public electricity supplies to the rural areas, a vast amount of capital is being invested in this development. The return on this capital is far too low and will remain so unless a full use of electricity is made for farming purposes. The Board's report indicates how the many farms already connected to the electricity mains and those now being afforded a public supply can, by making a good and wise use of electricity, produce a worthwhile return of their capital investment and at the same time help the Electricity Boards. The reports represent a valuable contribution to research into farm electrification.

MARSHALLING AT MARGAM

The working of marshalling yards has long fascinated writers on railway subjects. When Francis S. Williams surveyed the night scene at Toton he was moved to write that "Cosmos reigns amidst this seeming chaos; and the multifarious and apparently bewildering transactions are carried on with order, precision and security." This was in his book *Our Iron Roads* of 1885; the passage of years may cause other thoughts to be suggested to a modern observer of a mechanised hump yard. At Margam recently, which we visited at the invitation of Associated Electrical Industries - GRS, Ltd., the wagons rolling by gravity into the sorting sidings reminded us rather of a well-planned barrage of guided missiles, pinning down and confusing those who sought to cross the tracks.

We described the highly mechanised yard at Margam, between Bridgend and Port Talbot, in our April 22, 1960 issue, and we need therefore only recall that routes into the sidings are set by punched tape, while wagon speed is controlled by retarders responsive to signals from an analogue computer whose inputs represent "rollability," distance to run, and nature of route. In order that wagons may be released from the retarders at the speeds computed as correct for them to "buffer up" gently with those which have preceded them into the sidings, actual speed is measured by a Doppler system. Since the yard was opened, the Western Region of British Railways has been able to increase the throughput of wagons from about 1500 to some 2500 wagons in a good working day; as many as 1100 have been dealt with in six hours. Various lessons have naturally been learned from operating experience, and some phenomena have yet to be explained. For example, some loss of range with the Doppler equipment has been experienced in snow, although this has not been reported from a similar installation at Thornton in the Scottish Region. It appears that the Doppler signals are more attenuated by snow when it is damp than by the hard-frozen flakes in the Fifeshire yard. Again, there is some evidence that signals are scattered by the domed ends of certain tank wagons, resulting in loss of strength at the receiver.

Semiconductor techniques naturally figure largely in the equipment; their advantage to the railway operator lies entirely in economy of space and power. The trend is direct from electromechanical devices to transistors and diodes without the intermediate step of electronic valves. Ultra-fast operation is not required. Indeed, extreme sensitivity in switching transistors may be an embarrassment in signal engineering. The yard now coming into operation at Ripple Lane, Barking, equipped by the same main contractor, is similar in principle to Margam but makes further use of semiconductors in substitution for electromechanical methods. An example is the replacement of uniselectors by semiconductor devices for registering the occupation of sidings. Factors beyond the control of those who designed and operate the yard at Margam have prevented it from working at its capacity of 4000 wagons a day. The potential importance of merchandise traffic to the railways has been stressed recently by the new chairman of the British Transport Commission, and techniques such as those used at Margam for the expeditious formation of trains are a necessary background to other measures for serving the trader. It is a lesson

long understood by the railways. Of Margam and Ripple Lane we can echo the comment on the yard at Ashton Moss of a former Great Central Railway handbook for traders published in 1913: "The construction of the sidings has been carried out on the most up-to-date system, the wagons being shunted and sorted for dispatch on the principle of gravitation to facilitate prompt transit."

PRESERVING FOR POSTERITY

In recent years there has been an increasing — and welcome — awareness that there are other kinds of history besides political and economic, and that technology has played at least an equally important part in world development. There are, in fact, those who say it played a greater part. Be that as it may, the efforts which have been, and are being, made to preserve and display suitable relics of technical interest are generally approved by the public. But those who have to organise the preservation do not have an easy task. Peculiar to the work of the technical historian and museum worker is the problem of what to preserve. In the case of older objects the problem is often solved conclusively if unsatisfactorily by the fact that all those things which ought to have been kept have been scrapped, thoughtlessly, long ago.

We may deplore, but we cannot change, the actions of our predecessors. What we can do is to avoid repeating their mistakes. Those who have had much to do with technological history know only too well that much has been lost to posterity simply through ignorance and because of a strange idea that anything which is not "old" is of no importance. What is meant by "old" is never stated or even, it seems, understood by those who so glibly use the phrase "not old enough to be of interest." True, they will agree that James Watt's engine of 1777, now safely preserved after many vicissitudes and a period when it nearly perished for lack of attention, is old enough. But history is simply a continuous record of events. Something quite new may, if it represents a significant development, be of great importance. The first British jet aircraft, for example, is in the Science Museum, fortunately. It is not very old, but who could dispute the profound effect on the world which this exhibit represents? Birmingham Museum has a little horizontal steam engine of the 1890's. It is not really very old and, incidentally, it is not, for its time, very unusual either. In fact it is a very ordinary little engine, wherein lies its great interest. It represents a highly successful class of machine made literally by the thousand, and marks a definite stage in the development of mechanical power.

Age, then, is not all. An exhibit should teach us something. It should represent a development or a stage of development. To do this it can be old or new. It must simply be seen in its proper perspective, as a part of the continuing picture of mechanical development. What about the common electric motor, for example? It is a thing so commonplace that one buys it "off the shelf", uses it, forgets about it, and scraps it sooner or later when its work is done. To-day there are tens, hundreds of thousands of electric motors. Who knows how many there will be in, say, fifty years from now? Let those who would scrap because a thing is common or "not old enough" remember that Watt's engine of 1777 would not have been one of our prize possessions to-day if somebody had scrapped it years ago because it was "not old enough to be of interest."

RESEARCH ON ROAD INJURIES

We cannot work up much enthusiasm about the first progress report of the Road Injuries Research Group at the Birmingham Accident Hospital. The Group was formed about ten months ago and is financially supported by the Automobile Association. It operates by analysing the nature of the injuries suffered by those involved in road accidents and admitted to the hospital; some on-site studies are made principally to discover the source of particular injuries. The Group discoveries so far seem to amount to the confirmation of the work of others and they have led to conclusions about the design of vehicles which have been drawn elsewhere, notably at the Road Research Laboratory. The frequency with which passengers are ejected from cars when there is an accident has been noted and the conclusion drawn that safety harness, by holding passengers in their seats, can save lives. The importance of removing projections from the exterior of cars is stressed. So is the need to pad parts of the interior. A suggested design for a safer car illustrates the report. Attention is drawn to the desirability of fitting side and rear bumpers to lorries to prevent cyclists and pedestrians falling under them or being flung under them in an accident, or following vehicles penetrating under them from behind with often fatal results for the occupants. The need to improve lorry drivers' vision of the road in front of and almost beneath them is stressed. Personal protection by helmets and the like is deemed the most promising hope for improving the safety of motor cyclists and pedal cyclists "in what remains an unpromising situation." Nothing particularly new and all rather small beer! But it is unkind to be critical of the work of a group of people who have only just started a research. We look to the Group's next Report to learn whether anything more original is likely to emerge from that work.

The Engineer—100 Years Ago (JULY 26, 1861).

"Compressed Coal"

"Upwards of eighty patents have been obtained, at various times, for processes for compressing fine coal, generally in mixture with some one or more substances causing it to cohere together. Pitch is a favourite ingredient, and in some kinds of 'patent fuel' 15 per cent of this substance enter into the composition of the whole. Since, however, coal is already sufficiently bituminous it is not rendered exactly smokeless by the addition of pitch, or any other cementing hydro-carbon." "Nearly a dozen years ago, Mr. Henry Bessemer conceived the sensible idea of cementing bituminous coal 'slack' by its own pitch, first warming it just enough to bring out the tarry matter solidified in its pores, and then pressing the whole together. Another inventor, Mr. Spottiswoode, the Queen's printer, contrived a machine just adapted to this process, and very lately a company has been formed under an influential direction, which has purchased both patents, as well as others in the same line, and which it is expected, will soon have a new article of fuel on the market."

"The compressed blocks will have the same density as solid coal, from 31 to 34 cubic feet weighing a ton, instead of from 44 to 50 cubic feet, the bulk of a ton of loose coal. The original constitution of the coal being preserved, without adulteration by pitch, clay, &c., the compressed coal gives off no more soot to choke the tubes of the boiler, or clinker to choke the fire bars, than ordinary coal. The cost of compression is estimated at 2s. per ton, a machine worth £350 being expected to get through 28 to 30 tons a day."

A Locomotive History—The "Atlantic"

By E. C. POULTNEY, O.B.E.

No. I

"The most important part of a high-speed locomotive is its boiler capacity, for as speed increases so will the demand for steam, the distance travelled in a given time being greater and the train resistance augmented; consequently, larger cylinders are required, and, therefore, steam must be more rapidly provided."

JOHN A. F. ASPINALL,[1]
International Railway Congress,
London, 1895.

PROMINENT amongst the locomotives exhibited at the Columbian Exposition, Chicago, 1893, were two locomotives of great interest, both historically and when judged from the standpoint of design and construction, specially intended for high-speed passenger services. These notable locomotives, representing the work of well-known designers, were respectively F. W. Webb's compound express passenger engine "Queen Empress," the second of the "Greater Britain" class (Fig. 2), completed at the Crewe Works in 1892, and (Fig. 1), an experimental locomotive designed and constructed at the Baldwin Locomotive Works, Philadelphia, Pa., U.S.A., named "Columbia," for the purpose of showing a new design especially suitable for high-speed passenger traffic on account of the wheel arrangement adopted, allowing of the provision of greater boiler steaming capacity when compared with locomotives having the conventional 4–4–0 wheel arrangement known as the "American" type, then universally in use on the American railways. It is an interesting fact that, presumably by a unique concurrence of events, these two locomotives which, differing largely in certain respects, had both the same wheel arrangement and also cylinders arranged on the compound principle, should find themselves side by side, so to speak, as exhibits portraying new features in locomotive engineering. While F. W. Webb's three-cylinder system, as applied to the engine "Queen Empress," found little favour, the advent of these engines on the London and North Western Railway stimulated interest in the use of compound expansion cylinders on the world's railways. Similarly, the engine "Columbia" also attracted attention on account of the possibilities seen for raising boiler capacity and the power of steam locomotives.

THE LOCOMOTIVE "COLUMBIA"

Though the locomotive "Columbia" (Fig. 1) cannot claim to be the first to have the 2–4–2 wheel arrangement, the type having been already in use on certain Continental lines—notably in France and Belgium—it can, nevertheless, be said to be the most important example of this form of construction ever built, on account of its influence on later practice. If reference is made to the report on "Express Locomotives," presented by Mr. (later, Sir) John A. F. Aspinall, previously mentioned, illustrations will be found of seven different locomotives of this type, five being of French or Belgian origin and two built by Baldwin, one being "Columbia" and the other, also a compound, built for the Philadelphia and Reading Railway. Fortunately, through the courtesy of the Baldwin-Lima-Hamilton Corporation, the writer is able to illustrate the engine "Columbia," possibly, as previously suggested, the most important locomotive built in relatively modern times, being, as it unquestionably was, the forerunner of all designs incorporating trailing carrying wheels, whether applied in the form of single or multiple axle trucks.

The leading dimensions will be found in Table I, and a few further more detailed particulars are given as follows. The total heating surfaces of 1478·2 square feet were made up of 1349·9 square feet contributed by 198 2in tubes 13ft 1¼in long between the tube plates and 128·2 square feet in the firebox. The engine and tender wheel base was 24ft 7in and measured in long tons the locomotive weight in working order 98 tons. The Vauclain compound cylinders were cast in half saddles, each comprising one h.p. and one l.p. cylinder with a common valve chamber fitted with a piston valve 10½in diameter, distributing the steam in the two cylinders. The valve travel in full gear was 5¼in imparted by Stephenson's valve gear.

[1] "Express Locomotives," Report presented to the International Railway Congress, London, 1895, by John F. Aspinall, THE ENGINEER, June 14, 21 and 28, 1895.

Fig. 1—The 2–4–2 locomotive "Columbia," Baldwin Locomotive Works, 1893

The basic idea underlying the adoption of the 2–4–2 wheel arrangement was the opportunity afforded for the provision of a large boiler with an ample firebox with a large grate area not, however, exploited in this first design, but evident in the remaining examples given in the table, which also includes particulars of current practice in the design of 4–4–0 type locomotives—see also Figs. 3 and 4. The Chicago Burlington and Quincy (C.B. and Q.) engine of the 2–4–2 type was, in point of fact, the first engine ever built with a deep wide firebox which ultimately became standard practice when burning bituminous coal, in conjunction with a wheel arrangement incorporating a trailing pair of carrying wheels. It may, therefore, be fairly claimed that the 2–4–2 type locomotive "Columbia" undoubtedly pointed out the direction that developments ultimately followed and for this reason, therefore, constituted a design of outstanding historic interest and importance.

LOCOMOTIVES OF THE 4–4–0 AND 4–4–2 TYPE

Brief mention may perhaps be made of the basic differences in these two locomotive types for the reason that the 4–4–0 on North American Railways attained larger proportions than elsewhere on account of the much more liberal loading gauge prevailing, allowing both greater height and width. In the matter of boiler size, the American 4–4–0 had usually much more heating surface and, generally, more grate area than on British railways. So far as the latter feature is concerned, the less severe height limitations permitted the narrow type of firebox for the 4–4–0 type to be raised to rest on the top of the bar frames, thus allowing the inside width for the firebox proper to be increased to about 3ft 6in, making grate areas of 30 square feet, or, in some instances, about 36 square feet permissible. Total heating surfaces well over 2000 square feet being common, it is clear that comparatively powerful locomotives were possible.

TABLE I—*Comparative Dimensions of 4–4–0 and 2–4–2 Locomotives American Practice. Period* 1892–1900

Column Number	1	2	3	4	5	6	7
Date	1892	1893	1895	1899	1900	1893	1895
Type	4–4–0	4–4–0	4–4–0	4–4–0	4–4–0	2–4–2	2–4–2
Railway	N.Y.C. & H.R.R.	Penn R.	Penn R.	C. & N.W.R.	N.Y.N.H. & H.R.	"Columbia"	C.B. & Q.R.
Cylinders, diameter and stroke, in	19×24	18½×26	18½×26	19×26	20×26	19×26	19×26
Driving wheels, diameter, in	86	68	80	80	78	84½	84
Steam pressure, lb per square inch	190	175	185	190	200	200	200
Tractive force, lb	16,230	17,970	17,500	18,950	22,700	14,450	19,000
Total heating surface, square feet	1930	1571	1905	2353	2109	1478·2	1580
Grate area, square feet	30·7	33·2	33·2	30·2	30·3	24·0	44·4
Weight on driving wheels, lb	84,000	79,500	93,100	87,200	91,700	83,100	86,200
Weight on driving wheels, tons	37·5	36·1	43·2	38·95	42·2	37·2	38·45
Engine weight, lb	124,000	114,500	134,500	135,800	139,200	126,600	138,600
Engine weight, tons	55·18	50·58	60·1	60·61	62·19	56·6	61·9
Factor of adhesion	5·18	4·4	5·3	4·6	4·0	5·75	4·55
Figure number	3	—	—	4	—	1	—

THE FIRST "ATLANTIC"

Locomotives built with the 2–4–2 wheel arrangement, though enjoying a limited amount of favour under certain conditions, were not, however, found entirely suitable for high speed services, which suggested the provision of a four-wheeled truck or bogie in place of a single pair of wheels at the leading end. Thus the 4–4–2 wheel arrangement became an accomplished fact, being simply "Columbia" repeated, but with a leading four-wheeled truck taking the place of a single pair of wheels.

Such a design, prepared and built at the Baldwin Works in 1894 especially for the Atlantic Coast line for passenger services, revolutionised the whole concept of locomotive design and construction for maximum power requirements—see Fig. 5. This famous locomotive, though of modest proportions, is, even so, one of the most important ever built. Looked at objectively,

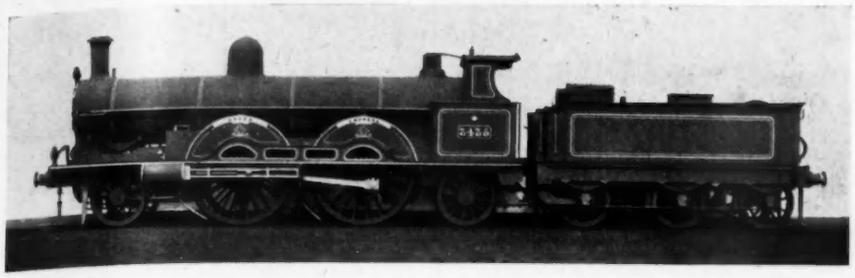


Fig. 2—Compound locomotive on F. W. Webb's system : " Queen Empress," L.N.E.R., 1892

all that had been done was simply to place the coupled wheels ahead of the firebox, thus following a plan adopted during the very early years of locomotive development, though for entirely different reasons. This is, however, but an interesting commentary on the fact that modern practice in locomotive design has so often proved to be little more than the embellishment of earlier ideas and practices.

At this point and before remarking on this design, it may be proper to point out that this particular 4-4-2 locomotive represents the true " Atlantic," the name given to it by its originators because, as already mentioned, it was first built for the Atlantic Coast Line. Normally, locomotives having a leading four-wheeled truck or bogie, followed by four coupled wheels and a single pair of wheels at the trailing end, are all called " Atlantics," which is, strictly speaking, incorrect. To be an " Atlantic," the wheel plan described must have outside cylinders driving through the medium of the second pair of coupled wheels. From the abridged particulars of the Baldwin " Atlantics " of 1894, given in Table II, it will at once be realised that, from the viewpoint of boiler heating surfaces and in the size of the grate, no improvement in their their dimensions is seen compared with modern 4-4-0 locomotives, known in North America as the " American " type. The dimensions given of examples of this type current at about that time show this to be the case.

The first " Atlantic," though of quite moderate proportions, quickly attracted the attention of other lines, resulting in locomotives of the same type being placed in fast passenger traffic. Particularly was this the case on certain Eastern lines, such as the Philadelphia and Reading and the Central Railroad of New Jersey, both of which used boilers having Wootten pattern fireboxes to suit the class of coal burned. The " Atlantic " not only allowed of larger boilers, but was especially suitable for this form of firebox with a large grate area, augmented in size commensurate with enlarged heating surfaces.

" Atlantic " type locomotives built by the Baldwin Works for these lines embraced designs of outstanding merit, either with Vauclain compound or with simple expansion cylinders. Such a design having compound cylinders arranged on the Vauclain superimposed system is illustrated by engine No. 1027, built by Baldwins in 1896 for the Philadelphia and Reading Company's fast trains operating on the Atlantic City Railway. Very similar designs were soon in evidence on the " Jersey Central," working fast services on the Philadelphia and New York run.

Notable " Atlantic " Locomotives

In May, 1896, the Baldwin Locomotive Works completed the first two of a total of thirteen compound " Atlantic " type locomotives specially designed for fast passenger service on the Chicago, Milwaukee, St. Paul and Pacific Railway. In some respects these engines are of particular interest for the reason they were designed to comply with operating conditions involving a guaranteed performance. The Milwaukee was confronted with the necessity of providing locomotives of increased power for passenger services between Chicago and Milwaukee, a distance of 85 miles to be run in one hour and forty-five minutes, operating trains of nine cars of not more than 70,000 lb each, say, 31·25 long tons, while complying with certain conditions as stipulated by a guaranteed performance.

A copy of the actual guarantee as given in the specification covering the construction of these locomotives reads as follows :

GUARANTEE

" Run between Union depôt Chicago, and Union depôt Milwaukee 85 miles, with a train of nine cars of an average weight of not more than 70,000 pounds per car. Must be made in one hour and forty-five minutes, with the following conditions :

" (*a*) Time between Union depot Chicago, and Forest Glen, a distance of ten and two-tenths miles, must be twenty-three minutes.

" (*b*) Time between National Ave. and Union depôt Milwaukee, distance of eight-tenths miles, must be five minutes.

" (*c*) Time between Forest Glen and National Ave., a distance of seventy-four miles, must be seventy-seven minutes, including four slow ups for railroad crossings at Rondout and Ranney, one slow up to take water from track tank at Wadsworth, one slow up for Kinnikinnic drawbridge and one stop for passengers at Western Union Junction."

Further conditions imposed were as follows : maximum loading on the coupled wheels not to be more than 18,000 lb per wheel, or a total of 72,000 lb, equal to 32·14 tons (2240 lb); maximum height 15ft and maximum wheel base engine and tender 57ft to suit existing turntables. The actual dimensions are given in Table II and some additional particulars relating to the boiler dimensions are as below.

Heating Surfaces

264 2in diameter tubes, 15ft long...	2061·8 square feet
Firebox	171·0 square feet
Total...	2232·8 square feet
Grate area	30·2 square feet

Table II—*Examples of American " Atlantic " Type Locomotives Period* 1894–1905

Column number	1	2	3	4	5	6	7	8
Date	1894	1896	1896	1896	1899	1900	1903	1905
Railway...	A.C.L.	C.M.St. P. & P.R.	P.Y.R.R.	P.& R.R.	C.R. of N.J.	C. & N.W.R.	P. & R.R.	N.Y.C. & H.R.R.
Cylinders, diameter and stroke, in ...	19×24	13/22×26	13/22×26	18½×26	14/24×26	20×26	21×24	21½×26
Driving wheels, diameter, in	72	78	84½	84½	84½	80	84½	79
Steam pressure, lb per square inch ...	180	200	200	200	200	200	225	180
Tractive force, lb	18,400	15,600	14,450	18,400	17,000	22,100	24,000	23,300
Total heating, square feet...	2047	2232·8	1835	1835	2669	3016	3048	3321
Grate area, square feet	26·2	30·2	76	76	76	46·8	80	50·3
Weight on driving wheels, lb	7,400	71,600	78,600	80,000	87,860	90,000	94,300	108,000
Weight on driving wheels, tons... ...	33	31·95	35·2	35·7	39·2	40·15	42·1	47·2
Engine weight, lb	126,000	140,700	142,900	149,000	163,500	160,000	178,600	193,000
Engine weight, tons	56·25	62·8	63·15	66·5	73·9	71·4	79·6	86·2
Factor of adhesion	4·1	4·6	5·44	4·35	5·16	4·08	3·93	4·12
Figure number	5	—	6	—	—	8	—	9

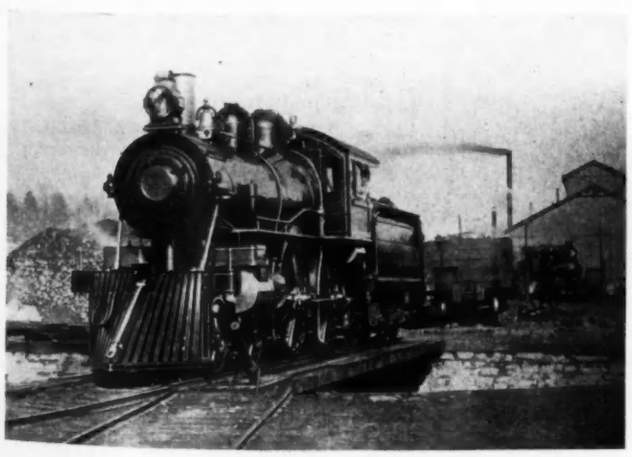


Fig. 3—W. Buchanan's 4-4-0 type locomotive, No. 999, built at the West Albany shops for the New York Central, 1892

The Vauclain compound cylinders have the following dimensions : h.p. 13in diameter ; l.p. 22in diameter ; common stroke 26in. They were formed in two half saddles, each comprising one h.p. and one l.p. cylinder with a common valve chamber, and were cast from a pattern one size larger than for the finished dimension given, thus allowing for the fitting of a larger piston valve and larger steam ports. The valve size was 11½in diameter compared to the standard size of 10½in for cylinders of the dimensions given. Stephenson's valve gear provided a full gear valve travel of 5½in.

These dimensions, together with 78in driving wheels and steam at a working pressure of 180 lb per square inch, provided a maximum tractive effort, working compound, of 15,600 lb, which, with 71,600 lb on the four coupled wheels, have a factor of adhesion of 4·6. Referring to the performance of these locomotives when operating under the conditions imposed by the terms of the guarantee, it will be noted that the time allowed for the 74 miles between Forest Glen and National Avenue, Milwaukee, was 77 minutes including all delays ; the journey time speed was, therefore, 57·5 m.p.h. The weight of the train only would be 281 tons (2240 lb) without any allowance for passengers.

How much time is represented by the four slow downs and the one station stop

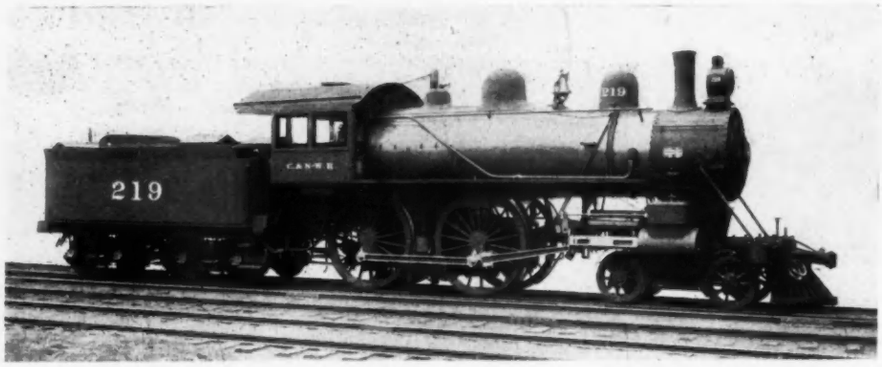


Fig. 4—Passenger engine 4–4–0 type, built for the C. & N.W.R.; Schenectady Locomotive Works, 1899

can only be a matter of conjecture. If, however, it be taken as being, say, eight minutes, and it may well have been more, the net or actual running time would be 69 minutes for the 74 miles, meaning an average speed of 64·5 m.p.h. The road for the most part is level or nearly so, skirting Lake Michigan for much of the distance. At that period it is probable specific train resistances were somewhat higher than at the present time, because modern coaching stock, combined with heavier rail sections and well maintained permanent way, have resulted in comparatively low resistance values. It may, therefore, be reasonably assumed that the drawbar tractive effort to work these trains would be somewhat high in relation to modern standards.

In view of the interest taken in the performance of these locomotives, the writer has prepared an estimate of the powers required to be developed by the engines. The L.M.S. train resistance values have been used to determine the powers required at the tender drawbar and also the resistance offered by the locomotive.[2] The sum of the two values would then represent the cylinder horse-powers. To comply with track conditions and rolling stock construction in 1896, train resistances have been increased by 10 per cent —a purely arbitary measure admittedly, though possibly reasonable.

For the train of nine coaches equal to 630,000 lb or 281 tons (2240 lb), the power required at a running speed of 64·5 m.p.h. is, therefore, $2811 \times 3 \cdot 2 \times 64 \cdot 5/375 = 640$ h.p.

For the locomotive weighing 243,700 lb equal to 108 tons (2240 lb), the power required is $108 \times 23 \cdot 92 \times 64 \cdot 5/375 = 443$ h.p. The total or i.h.p. necessary is, therefore, 1083. In practice, the power required would no doubt be somewhat higher.

Consideration will now be given to a special run performed by one of these engines with a much heavier train, the conditions being as follows. Weight of train thirteen cars, total 956,300 lb equal to 426 tons (2240 lb) locomotive as before, 108 tons. Time between Forest Glen and National Avenue, 74 miles, 82 minutes, including one station stop of five minutes and slow downs, which would be, presumably, as previously given. In this case, the net running time would be, say, 73 minutes if the one station stop and the speed reductions accounted for nine minutes. The average speed may then be taken as 61 m.p.h., but with a much heavier train.

The average drawbar horse-power required would be $426 \times 12 \cdot 1 \times 61/375 = 840$ h.p. The locomotive would require $108 \times 20 \times 61/375 = 352$ h.p., making a total of 1194 h.p., which would be the i.h.p. developed by the locomotive. The particulars here given of the running conditions are taken from "Baldwin Locomotives," October, 1930.

The higher figure of 1194 i.h.p. in the first place, implies the development of 40 i.h.p. per square foot of grate area per hour, and, secondly, it allows 1·87 square feet of heating surface per i.h.p. hour. The heating surface grate area ratio is 74·4, which would probably allow of a fairly high rate of evaporation and steam supply per square foot of heating surface per hour at reasonable rates of firing.

The Reading "Atlantics"

The Philadelphia and Reading "Atlantics" already mentioned, one of which, No. 1027, is illustrated in Fig. 6 were specially built to work important fast passenger services operating between Philadelphia and Atlantic City, N.J., a highly competitive traffic. Built in 1896, this locomotive represents the rapid advance made in the development of the "Atlantic" type for high speed passenger service since the initial design of 1894. In addition it is representative of others built at the Baldwin Locomotive Works with either compound or simple expansion cylinders for the Reading and also for the Central Railroad of New Jersey, some particulars of which are included in Table II (see also Figs 8 and 9). The engine No. 1027 had, it will be seen, Vauclain compound cylinders of the same dimensions as those used for the Milwaukee "Atlantics," piston valves of the same size, 11½in, were also fitted, actuated by Stephenson's valve gear. The driving wheels are, however, of larger diameter, namely, 84½in as against 78in, and the working steam pressure is raised from 180 lb to 200 lb per square inch. Locomotives of this type established an excellent record in fast traffic on the Atlantic City run of 55·5 miles between Camden, N.J., and Atlantic City, at a booked average speed of 64 m.p.h. Actually, higher speeds were frequently necessary in order to obtain the punctual arrival times at Atlantic City considered to be imperative.

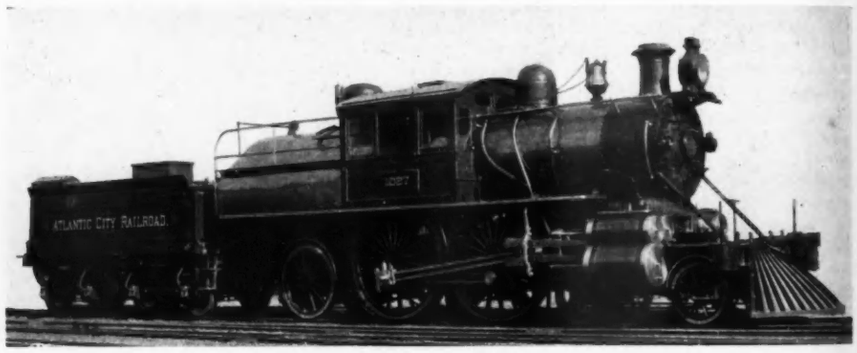


Fig. 6—Reading "Atlantic," Vauclain compound No. 1027

Running times of from 50 to 46½ minutes have been recorded, calling for mean speeds of 66·6 and 71·2 m.p.h. Both the engines built for the "Reading" and the "Jersey Central" used small sized anthracite coal, for which very large grates were required, which is the reason for the unusual position of the cab, midway to the length of the boiler. Much later, with the use of larger boilers having the barrel of greater diameter, this arrangement became impossible, resulting in a redesign, the cab being then placed in the more usual position behind the firebox. Such a locomotive of more recent construction is shown by the accompanying illustration (Fig. 7) of one of these later Reading "Atlantics" leaving the Philadelphia terminal with one of the New York fast trains. Locomotives of this class had

[2] "The Development and Testing of Locomotives," Sir W. Stanier, Section G, The British Association, 1936.

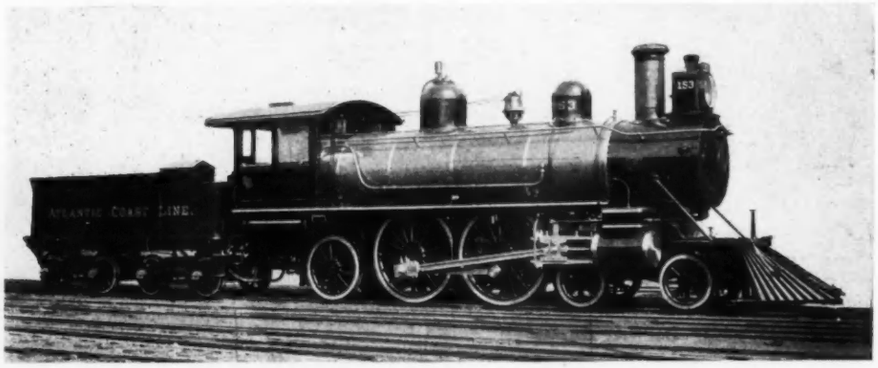


Fig. 5—The first "Atlantic," Atlantic Coast Line ; Baldwin, 1894

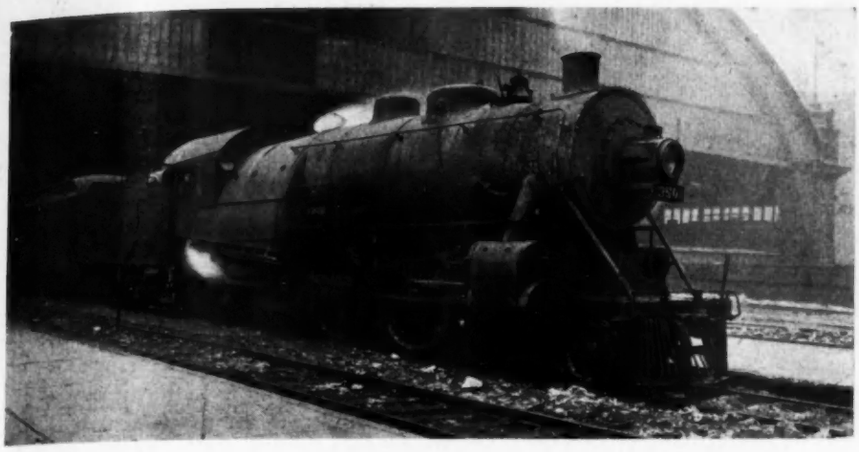


Fig. 7—A Reading " Atlantic " leaving the Reading terminal, Philadelphia

23½in by 26in cylinders, 80in drivers and a working steam pressure of 215 lb per square inch, thus giving a tractive force of 32,800 lb. The area of the grate was as much as 108 square feet. The weight of the engine and tender in working order was 124·8 tons. Unlike the engines previously mentioned, these had superheaters.

Pennsylvania " Atlantics "

While the history of the development of the " Atlantic " type locomotive is associated with a number of railways both in North Amercia, where it originated, and on British lines, on none is it of greater interest and, indeed, importance than on the Pennsylvania System. Such being the case, some special attention is due to the locomotives designed and built at the Juniata Shops, Altoona,Pa. (see Figs. 10, 11 and 12). The Pennsylvania probably made more use of the " Atlantic " than any other railway, as exemplified by the many successive designs built over the years extending from 1899 up to the year 1914 when the final Class E6s appeared, representing an outstanding achievement in locomotive designing and construction. Through the courtesy of the motive power authorities, it is possible to illustrate three steps taken in the development of the " Atlantic " locomotives and in main line passenger services for many years.

The first locomotives of the " Atlantic " type to be built for the Pennsylvania Railway at Altoona are illustrated by the photograph of engine No. 820. The design, it will be seen, was in general very similar to the Reading locomotive No. 1027 ; that is to say, the driver's cab was placed in the same position, considered necessary on account of the large Wootten type firebox being also adopted for this new Pennsylvania design.

The rods were of fluted section of light weight, consistent with the required strength, and the crossheads were likewise of light weight, working in trough-shaped guides, made in two parts bolted together by horizontal bolts and, when assembled, open at the bottom. The upper and lower surface took the connecting rod reactions when running in foregear, while, when running tender first, the two lower lips served to take the thrust. The crossheads were steel castings in one piece only.

This type of crosshead and attendant guides had been used for the 4–4–0 locomotives Class 16Da, which were designed by Axel Voght. These " Atlantics " had 20½in by 26in cylinders with American balanced slide valves having a steam lap of 1¼in and a full gear travel of 7in when the cut-off was at 83 per cent and a negative lead of $\frac{1}{32}$in. The weight on the four coupled 80in wheels was 101,550 lb, which with a maximum tractive force of 21,480 lb gave an adhesive factor of 4·74. The large increase in boiler heating surface to 2320 square feet, combined with a grate area of 68 square feet, as against 1905 square feet of heating surface and 33 square feet of grate area for the 4–4–0 locomotives, indicates the considerable advance made in boiler power consequent on the introduction of the " Atlantic " type. These new locomotives were in all respects successful in the fast passenger services for which they were intended, though objections were raised to the position of the driver's cab necessitating the separation of the enginemen.

A modified design, classified E1a, was, therefore, prepared and one engine built for trial purposes. This had a rather smaller firebox, 66in wide, and had the cab at the rear in its usual place. In 1901 a further similar design was completed with a wider firebox of 72in, but like the Class E1a engine of the radially stayed type. The new engines, Class E2, also had boilers with rather more heating surface, but the principal feature was the increase in the boiler steam pressure from 185 lb to 205 lb per square inch, which became the standard steam pressure on the Pennsylvania for many years. In so far as the cylinders and motion were concerned, the new engines were the same as the original E1 of 1899, but both the E1a and E2 classes had the rear carrying wheels spaced further back from the trailing coupled wheels, with which they had equalised springing.

Further developments taking place were the enlargement of the cylinders to 22in and the fitting of Belpaire type boilers. The engines with 22in cylinders and radially-stayed firebox boilers were classified E3, and, when these and the engines having 20½in cylinders were modified by having Belpaire pattern boilers, they became Classes E3a and E2a respectively.

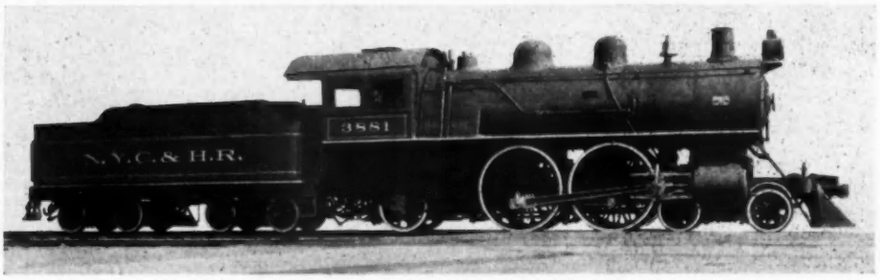


Fig. 9—" Atlantic " type locomotive for the N.Y.C. & H.R.R. ; Schenectady, 1905

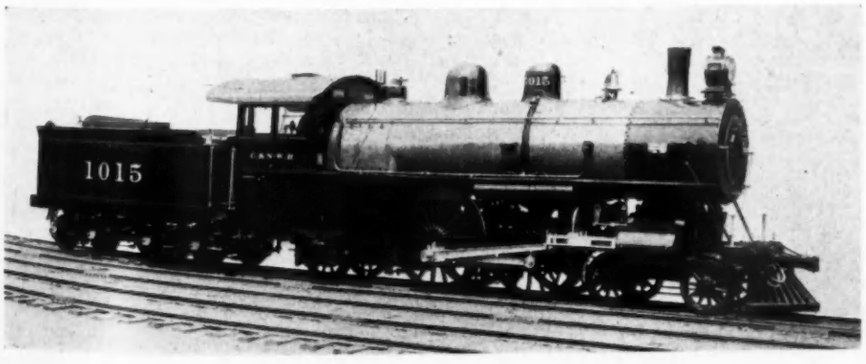


Fig. 8—" Atlantic " type locomotive for the C. & N.W.R. ; Schenectady Locomotive Works, 1900

The first " Atlantics " of 1899, Class E1, as previously mentioned, performed very well in the fast passenger services for which they were built, as also did the more powerful E3a Class with 22in cylinders, and at this point attention may fittingly be drawn to a letter printed in The Engineer of August 26, 1904, which illustrated and gave very full particulars of these two classes, E1 and E3a, and gave information as to their performance on the Atlantic City runs as well as during some special high speed trials.

On the Atlantic City passenger services, speeds of 93 m.p.h. were reported to have been attained, and similar high speeds were also recorded during the brake experiments. Following the Class E3a locomotives in 1906, a further series appeared, Class E3d, similar in all respects to E3a but having 22in cylinders with 12in piston valves and Walschaerts valve gear. In 1908 the locomotives of this class were further modified by being fitted with superheater equipment and classified E3sd.

In 1910 still further attention was given to the design of the " Atlantic " with the idea of providing locomotives of this type develop-

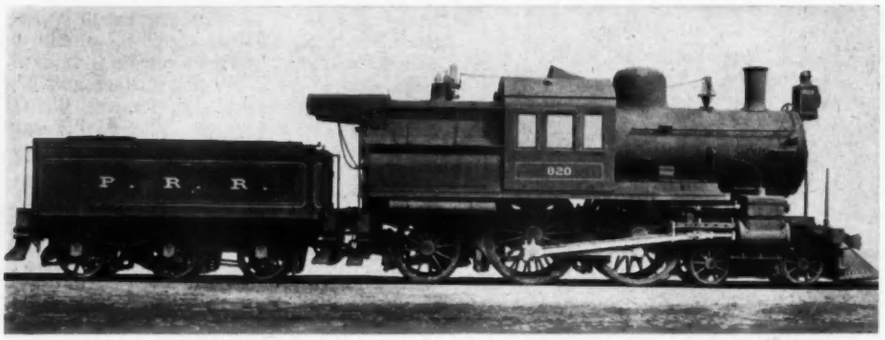


Fig. 10—The first " Atlantic " for the Pennsylvania Railway, built at Altoona, 1899

ing higher power. As a result, a further locomotive was built, similar with respect to the dimensions of the cylinders driving wheels and the boiler steam pressure to the Class E3 and E3sd locomotives, but having a much larger boiler with increased heating surfaces. In fast passenger service this engine gave an impressive performance. It was partially reasonably representative of the 4–4–0 type current at the time. Column 3 gives the dimensions of the Pennsylvania Class D16a of 1895. The dimensions of this locomotive may be compared with those in Table III, which will indicate an important and impressive development in the size and potential power output of locomotives of the four-

Column 2 by similar information for the Chicago Milwaukee, St. Paul and Pacific (C.M.St.P.&P.) compound locomotives of 1896. The next three examples with that shown in Column 7 have Wootten type fireboxes and are all generally similar to the Philadelphia and Reading engine No. 1027, Column 3. The examples given in Columns 6 and 8 have radially-stayed wide deep fireboxes of what may be called the normal type. The dimensions may be compared with those for the 4–4–0 locomotives, Table I, so bringing out the differences due to the " Atlantic " design.

The particulars given in Table I, Column 4, and those in Table II, Column 6, are of interest as making a comparison between 4–4–0 and " Atlantic " locomotives built for the same railway by the same builders, the Schenectady Locomotive Works, in 1899 and 1900 respectively. In general, the particulars given of the several examples of the " Atlantic " type may be taken as being representative of the locomotives as developed up to about the period when the larger

Fig. 11—" Atlantic " type locomotive, Class E.3sd, built at Altoona, 1908

rebuilt in 1912 and fitted with a modified boiler having a superheater, and two further locomotives of the same design were built. Later, in 1913, all three locomotives were fitted with larger cylinders, 23½in by 26in, thus raising the tractive force from 27,410 to 31,275 lb. As a result of this development, in 1914 the celebrated Class E6s engines were designed and first built at Altoona. The cylinders, coupled wheels and boiler steam pressure were the same as for the engines of 1913. The boilers were also of the same general design, providing a total heating surface, including the superheater, of 3698 square feet. With 136,000 lb on the coupled wheels, the adhesion factor was 4·3.

The foregoing outline of the development of the " Atlantic " for main line fast passenger service on the Pennsylvania, together with the chief dimensions of the principal classes given in Table III, will be sufficient to indicate the extent of this development extending from 1899 to 1914, during which the tractive force of the " Atlantic " design advanced from 21,480 lb to 31,275 lb, an increase of 50 per cent and engine only weight rose from 173,450 lb, 77·5 tons to 243,600 lb, 108·5 tons.

Comments on the Locomotives Tabulated

Referring briefly to Table I, it will be noted that the particulars given show boilers having heating surfaces of from 1571 to 2353 square feet and tractive efforts of from 16,230 lb to 22,700 lb.

The engine, the particulars of which are given in Column 1, Table I, is William Buchanan's engine No. 999 for the New York Central, which is illustrated as being

Table III—*Examples of " Atlantic " 4–4–2 Type Locomotives—Pennsylvania Railway Period* 1899–1914

Date	1899	1901	1902	1908	1910	1914
Classification	E1	E2	E3a	E3sd	E6	E6s
Boiler type	Belpaire	Radial stayed	Belpaire	Belpaire	Belpaire	Belpaire
Cylinders, diameter and stroke, in	20½×26	20½×26	22×26	22×26	22×26	23½×26
Valves	Balanced slide	Balanced slide	Balanced slide	12in piston	14in piston	12in piston
Valve gear	Stephenson	Stephenson	Stephenson	Walschaerts	Walschaerts	Walschaerts
Driving wheels, diameter, in	80	80	80	80	80	80
Steam pressure, lb per square inch	185	205	205	205	205	205
Tractive force, lb	21,480	23,800	27,410	27,410	27,410	31,275
Total heating surface, square feet	2320	2640	2670	2571	3582	3698
Grate area, square feet	68	55·5	55·5	55·5	55·1	55·1
Weight on driving wheels, lb	101,550	118,280	118,400	127,200	133,300	136,000
Weight on driving wheels, tons	44·8	52·80	56·78	56·78	59·5	60·75
Engine weight, lb	173,450	186,480	190,600	196,600	231,500	243,600
Engine weight, tons	77·5	73·3	85·05	87·55	103·2	108·6
Factor of adhesion	4·75	4·97	4·32	4·64	4·86	4·35
Figure number	11	—	—	12	—	13

—Note : E3sd engine heating surface includes superheater 533 square feet.
E6s engine heating surface includes superheater 806 square feet.

coupled type for heavy fast passenger service over a nineteen-year period from 1895 to 1914.

Particulars of selected examples of " Atlantic " type locomotives are given in Table II of which those in Column 1 apply to the first of the type for the Atlantic Coast Line (A.C.L.), built in 1894, followed in " Pacific " type was commencing to attract attention. All these locomotives used saturated steam and with the exception of certain "Atlantic" designs built for the P. & R. and for Pennsylvania, comparatively few engines of this type were built with superheaters.

(To be continued)

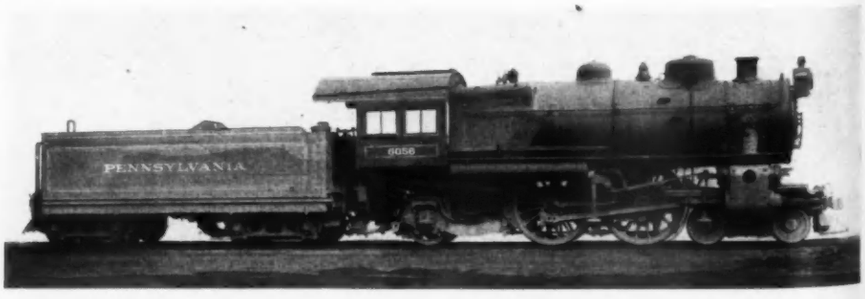


Fig. 12—" Atlantic " type locomotive, Class E6s, 1914. The final design for the Pennsylvania

THE ENGINEER

Technical Contributors Section

JULY, 1961

Efficiencies of Reciprocating Compressors Pumping Town Gas

By G. T. PAUL, A.M.I.C.E., M.I.Mech.E.*

*The characteristics of centrifugal compressors have been established and the procedure for performance conversion between gases is covered in B.S.*2009 "*Acceptance Tests for Turbo Type Compressors and Exhausters.*" *For reciprocating compressors there is no similar procedure and B.S.* 1571 "*Acceptance Tests for Positive Displacement Compressors and Exhausters*" *says* inter alia, "*Where it is not possible to test a machine with the gas required by the purchaser, special conditions of test or special corrections shall be agreed between the purchaser and manufacturer.*" *In this article empirical formulae are suggested and the results of tests on air at the maker's works and on gas at site are shown to confirm them.*

COMPRESSORS designed to pump town gas can only be tested at the maker's works with air and from the results the performance on town gas is assessed. A recent series of tests has suggested some of the methods currently used can give incorrect results.

One calculation described in Appendix I assumes adiabatic conditions and takes into account only the difference in gamma values (1·4 for air and about 1·37 for town gas), and ignores the fact that the density of town gas is about half that of air. This method gives a volumetric efficiency on town gas only about 1 per cent less than that on air. No calculation for estimating the difference in power absorbed is, as far as is known, in general use and it has usually been assumed that with town gas the power required is between 5 per cent and 10 per cent less than for air. These two methods used together suggest that when pumping town gas, there is a not inconsiderable increase in adiabatic efficiency. There appears to be no reason for this and it is thought to be unlikely.

Recently it has been possible to carry out, with a reasonable degree of control, site tests on a recriprocating compressor pumping town gas and comparing the results with those obtained on the same machine during the works tests on air. Although the number of tests was limited, they indicated that the difference in volumetric efficiency was greater than is usually assumed, but that there is little difference in adiabatic efficiencies. The results of these tests together with suggested empirical formulae, are set out below.

The symbols used are given in a footnote below.

* Senior Engineer, Messrs. Mackness and Shipley, Consulting Engineers, S.W.1.

Symbols

η_v—Volumetric efficiency.
η_{ad}—Adiabatic efficiency.
V_s—Swept volume of piston in cubic feet.
V_c—Clearance volume of the cylinder at the end of the discharge stroke, expressed as a fraction of the swept volume.
R—Absolute ratio of compression.
γ—Ratio of specific heats.
n—Exponent of compression and re-expansion.
P_1—Compressor inlet pressure in pounds per square inch absolute.
v—Piston speed in hundreds of feet per minute.
d—Gas specific gravity relative to air.
M.c.f.h.—Thousands of standard cubic feet per hour.
p.s.i.a.—Pounds per square inch absolute.
B.h.p.—Brake horsepower.
W.G.—Water gauge.

VOLUMETRIC EFFICIENCY

Principles of Compression

Fig. 1 shows a theoretical pressure volume diagram for a single stage compressor. It will be noted that the compression and re-expansion are adiabatic and conform to the general law of PV^n constant, where n is equal to γ.

Fig. 2 shows the type of diagram obtained in practice. Due to cooling through cylinder walls and head the mean value of n lies between γ and unity, and the compression and re-expansion are no longer adiabatic. The diagram also shows the effects due to valve inertia and the drop in cylinder pressure during the suction stroke, caused by throttling through the inlet valves and passages. The symptoms of leaking inlet and discharge valves are indicated by dotted lines.

The volumetric efficiency of a compressor may be defined as the ratio of the weight of gas drawn in per stroke to the weight, at intake conditions, of a volume of the same gas, which is equal to the volume swept by the piston during the suction stroke. Theoretically this is equivalent to :

$$\eta_v = 1 - V_c\left(R^{\frac{1}{n}} - 1\right) \quad . \; . \; . \quad (1)$$

The Exponent of Compression and Re-Expansion

It is the exponent of re-expansion and not that of compression which determines the volumetric efficiency. The higher the value of this exponent, the greater is the volumetric

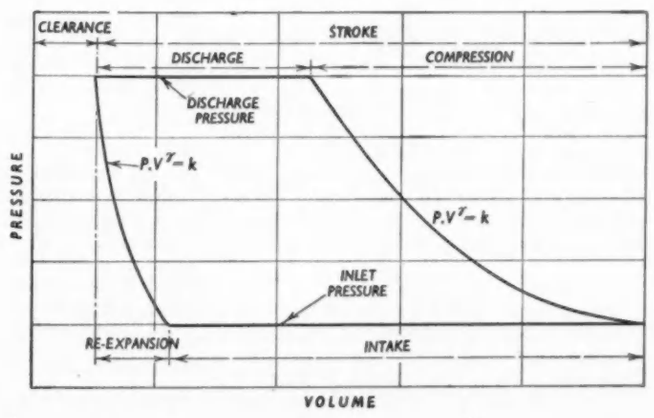
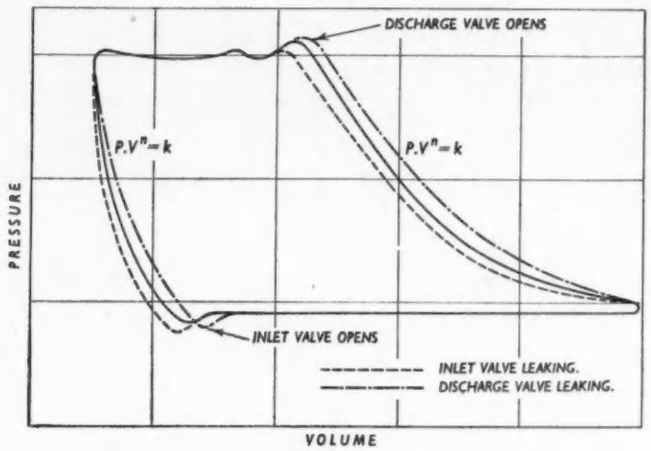


Fig. 1—Ideal pressure volume diagram

Technical Contributors Section (*continued*)



Effects of leaking inlet and discharge valves also shown.

Fig. 2—Indicator diagram obtained from compressor in good condition

efficiency. The value of the exponent may be obtained by replotting the pressure volume diagram on logarithmic paper and measuring the slope of the re-expansion curve.

It will be found that the value of n varies[1] at different parts of the cycle in the manner shown in Fig. 3. At the beginning of the compression stroke, the gas in the cylinder is at a lower temperature than that of the surrounding metal and so heat is transferred to it and n is greater than γ. As compression proceeds, the temperature of the gas rises until it becomes equal to that of its surroundings and at this point the values of n and γ are equal. Before the discharge pressure is reached, the temperature of the gas has risen still further and heat is transferred back to the compressor so the value of n falls to between γ and one. On the re-expansion stroke the gas is initially at a higher temperature than the compressor and so again the value of n is greater than γ. As re-expansion proceeds, so the value of n falls and if the clearance space is very hot, it may, just before the inlet valves open, fall to below the isothermal value of one. The value of this exponent is also affected to some extent by heat generated in piston and ring friction.

In practice it is difficult, owing to the

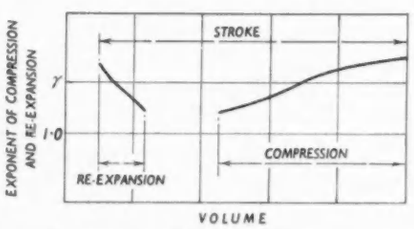


Fig. 3—Variation in value of n during compression and re-expansion

comparatively short re-expansion stroke, to obtain from indicator cards accurate values for n and it is generally assumed that the mean value during the compression and re-expansion strokes is the same. Where sufficient indicator cards cannot be taken, a value may be obtained from :

$$n=0\cdot75\gamma+0\cdot25 \quad . \quad . \quad . \quad (2)^2$$

This equation gives reasonable results for piston speeds of the order of 600ft per minute, but the lower the piston speed the closer, particularly in a water-cooled compressor, will the cycle approach isothermal conditions.

For piston speeds of the order of 300ft per minute, tests have shown that a more accurate expression is :

$$n=0\cdot75\gamma+0\cdot20 \quad . \quad . \quad . \quad (3)$$

Other Factors Affecting Volumetric Efficiency

Heating of the incoming gas, leakage past the piston and valves and valve losses reduce the volumetric efficiency to a value below that obtained from Equation (1). The greatest reduction is probably due to the heating of the incoming gas during its passage through the valve ports and clearance space. This causes the gas to expand and so its density and the weight drawn in per stroke is reduced. The higher the compression ratio, the higher will be the cylinder wall temperature and the greater this effect. Valve and piston leakage although depending on mechanical clearances and compression pressure are also affected by the physical properties of the gas being pumped.

The subject of gas leakage through small orifices is a complicated one. In turbulent flow the rate is inversely proportional to the square root of the gas density, but with streamline flow or under boundary conditions, it is a function of the viscosity. In a compressor probably all three conditions obtain. Piston speed will also affect the rate of leakage past the piston. The γ value of a gas has little effect on its flow or leakage characteristics and its effect on the exponent of re-expansion has already been discussed. It is probable that the property which has most effect on leakage and valve loss is gas density. For convenience the specific gravity relative to air will be considered. Valve loss, as distinct from valve leakage, will be affected by valve and port design and the valve spring stiffness. It will increase with increase of gas velocity.

A mathematical analysis of the various losses is beyond the scope of this article but they are functions of the gas compressed, the compressor design, the compression ratio, the piston speed and the gas velocity through the valves. For a given compressor the last two bear a linear relationship to each other. As it is easier to measure piston speed, this alone will be considered.

Summarising then :

$$\text{Volumetric losses}=K\,.\,f(R)\,.\,f(v)\,.\,f(d) \quad . \quad (4)$$

where K is a compressor constant.

Some Empirical Formulae for Volumetric Efficiency

A number of empirical formulae have been put forward. They are for a given gas in a machine running at constant speed. When the speed or the gas is changed the constants have to be adjusted accordingly.

The formulae are usually of the general form :

$$\eta_v=(1-b-xR)-V_c\left(cR^{\frac{1}{n}}-1\right) \quad . \quad (5)^3$$

where b, x and c are constants.

An American arrangements of this equation is :

$$\eta_v=K\left[1-V_c\left\{\left(\frac{R}{c}\right)^{\frac{1}{n}}-1\right\}-S\right] \quad . \quad (6)^4$$

where $1-c$ is the fractional loss in suction pressure due to wire drawing through the valves, and S is the fractional volume loss during the discharge stroke, due to leakage past the piston and valves.

Another form of Equation (5) is :

$$\eta_v=1-0\cdot01R-V_c\left(R^{\frac{1}{n}}-1\right) \quad . \quad (7)^5$$

Some engineers consider that better results are achieved by assuming isothermal expansion and use :

$$\eta_v=b-V_c(R-1) \quad . \quad . \quad . \quad (8)$$

A value of b between 0·9 and 1·0 is normally taken.

Tests on Air and Town Gas

It has recently been possible to carry out tests on a single-stage, two-cylinder, water-cooled, double-acting vertical compressor. The bore and stroke of the machine were 28½in and 12in respectively and the clearance volume 15 per cent of the swept volume. It was driven, through a gearbox, by a two-speed squirrel-cage induction motor to give compressor speeds of 306 and 155 r.p.m.

Tests on air ($\gamma=1\cdot4$, specific gravity 1·0) were conducted in accordance with British

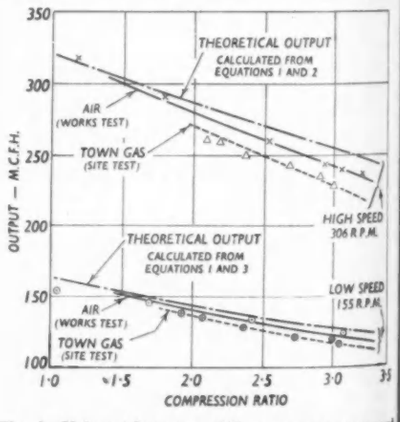


Fig. 4—Volumetric tests on 12in compressor compared with calculated volumetric output neglecting losses of Equation (4)

Standard 1571 at the maker's works and further tests were carried out after installation in the Southern Gas Board's Poole Works. Details of the latter are given in Appendix 2. The gas had a γ value of 1·37 calculated in accordance with British Standard 2009. The gas analysis and details of this calculation are in Appendix 3. The specific gravity of the gas, measured during

the test, was 0·472. The results of both tests are both shown in Fig. 4 on which also, has been plotted the theoretical volumetric output of the compressor calculated in accordance with Equations (1), (2) and (3). The difference between the calculated and the actual outputs represent the losses of Equation (4).

Suggested Empirical Formulae for Volumetric Efficiency Allowing for Varying Conditions and Different Gases

An analysis of the results plotted in Fig. 4 has led to the following empirical equation being put forward :

$$\eta_{iv} = 1 - K\frac{v^{0\cdot75}}{d^{0\cdot8}}R - V_c\left(R^{\frac{1}{n}} - 1\right) \quad . \quad (9)$$

The second term which represents the losses of Equation (4) contains the compressor constant K. Its value in the compressor tested was found to be 0·004. In a similar but smaller compressor it was 0·005. The value of the exponent n is obtained from Equations (2) or (3).

Comparison of Test Results with Suggested Formula

In Fig. 5 have been plotted curves, calculated in accordance with Equation (9), for the volumetric efficiency of the compressor when pumping air or town gas at speeds of 306 and 155 r.p.m. The actual results of the volumetric tests for these conditions are also shown. It will be seen that for air there is a good measure of agreement, but that for town gas there is a greater degree of scatter. This may be due to greater accuracy possible when working under test bay conditions.

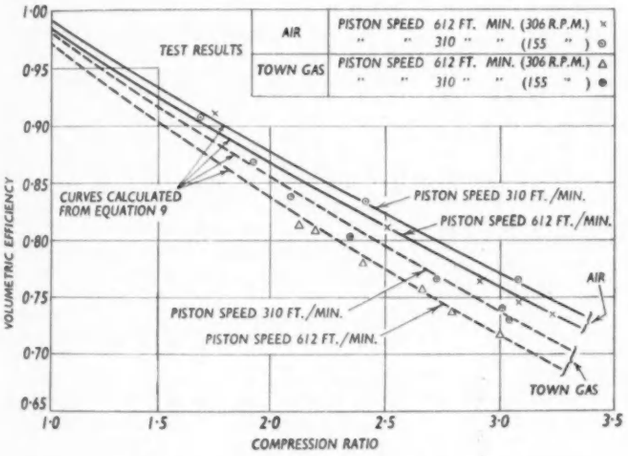


Fig. 5—Comparison of calculated and test volumetric efficiencies for 12in compressor

Use of the proposed equation shows that for a given gas the volumetric efficiency increases as the compressor speed decreases. This trend is confirmed by experience and it will be observed that under these circumstances the increase in volumetric efficiency due to the decrease in piston and valve losses, more than offsets the decrease due to the decrease in n as the cycle approaches the isothermal.

BRAKE HORSEPOWER

Standard Conditions

In measuring power requirements it is convenient to refer to the horsepower required to compress 1000 cubic feet of gas per hour. The gas flow is measured at the intake and the power absorbed adjusted for standard conditions. These are a temperature of 60 deg. Fah. and a pressure of 30in of Mercury. The compressor brake horsepower is taken as the power absorbed at the driving coupling after deducting any required to drive ancillary equipment, such as cooling water pumps, &c.

Indicated Horsepower

As with volumetric efficiency calculations, it is assumed that the value of the exponents of compression and re-expansion is the same and can be found from Equations (2) or (3).

Neglecting pumping and friction losses, the indicated power required for other than an isothermal cycle is :

$$\text{h.p./M.c.f.h.} = 0\cdot0729\,P_1\frac{n}{n-1}\left(R^{\frac{n-1}{n}} - 1\right) \quad . \quad . \quad . \quad (10)$$

For standard conditions this expression simplifies to :

$$\text{h.p./M.c.f.h.} = 1\cdot07\alpha \quad . \quad . \quad . \quad (11)$$

where

$$\alpha = \frac{n}{n-1}\left(R^{\frac{n-1}{n}} - 1\right) \quad . \quad . \quad . \quad . \quad (12)$$

The lower the value of n, the less is the power required for a given compression ratio. With an isothermal cycle the power required is :

$$\text{h.p./M.c.f.h.} = 2\cdot46 \log_{10} R \quad . \quad . \quad . \quad (13)$$

Compressor Efficiencies

The isothermal efficiency is the ratio of the isothermal horsepower, calculated from Equation (13), to the brake horsepower ; the adiabatic efficiency the ratio of the adiabatic horsepower, calculated from Equation (11), to the brake horsepower. Although neither of these cycles obtain in practice, the efficiencies are useful as standards of comparison. Mechanical efficiency is the ratio of the indicated horsepower, obtained from the indicator diagram, to the brake horsepower. It is a measure of the friction losses in the compressor and will be affected by the compression ratio and piston speed.

Power Losses

The principal factors causing the difference between the theoretical horsepower calculated from Equations (11) or (13) and the brake horsepower are pumping losses and mechanical friction. Pumping losses are influenced by the design of the valves, valve ports and passages and the relative positions of the suction and discharge valves. They are a function of the gas density, its velocity through the valves, and the machine design. The gas velocity is, for a given machine, proportional to the piston speed so, as with volumetric losses, this is the variable which it is most convenient to consider. Frictional loss is affected by rotational and piston speeds and bearing loads. It may be considered as a function of the compression ratio and piston speed.

Summarising :

$$\text{Power losses} = k \,.\, f(R) \,.\, f(v) \,.\, f(d) \quad . \quad . \quad (14)$$

where k is a compressor constant.

Test Results

Reference has already been made to a 12in stroke compressor, on which volumetric tests were conducted on air at the maker's works and on town gas in the Southern Gas Board's Poole Works. In addition to the volumetric tests the power absorbed was measured and the results are shown in Fig. 6. All have been corrected to a common inlet pressure of 30in Hg. It will be seen that for the same compression ratio the power absorbed when pumping gas is less than that when pumping air. The differences are about 9 and 6 per cent at full and half speeds respectively.

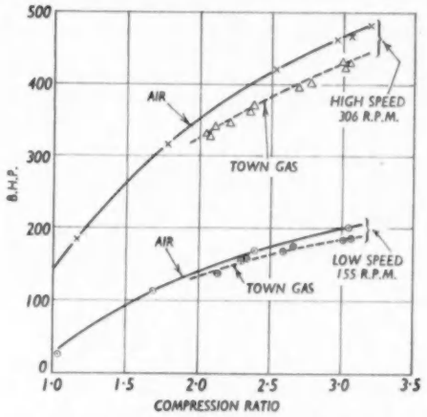


Fig. 6—Results of power absorption tests on 12in compressor

Using the results from these tests and assuming the volumetric efficiency as calculated from Equation (9), the adiabatic efficiency and b.h.p./M.c.f.h. have been calculated. These are plotted in Figs. 7 and 8 respectively. Also in Fig. 8 the corresponding theoretical h.p./M.c.f.h. calculated from Equation (11)

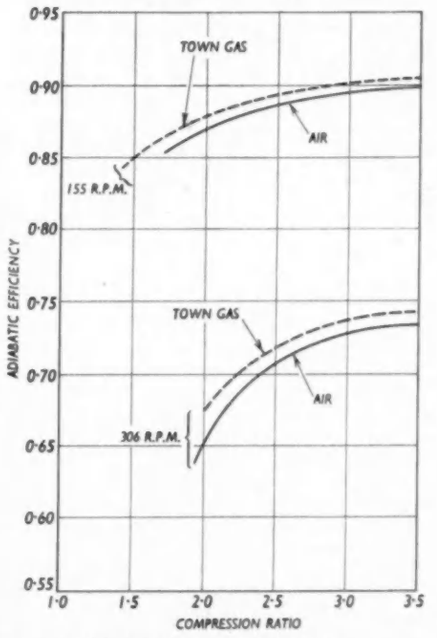


Fig. 7—Adiabatic efficiency curves of 12in compressor

Technical Contributors Section (*continued*)

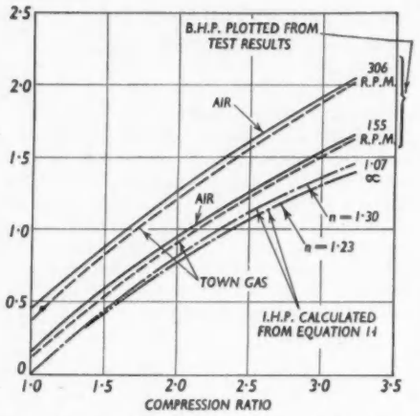


Fig. 8—H.p. per M.c.f.h. at various speeds for air and town gas on 12in compressor tests results shown in Fig. 5

has been plotted. As these four curves would come close together, the intermediate ones for half speed pumping of air and full speed pumping of town gas have been omitted. The differences between the indicated and actual curves represent the losses of Equation (14).

Suggested Empirical Formula

An analysis of these results suggested the following equation :

Power losses/M.c.f.h.

$$= k.v^{1.3}.d^{0.125}\left(1+\frac{R}{20}\right) \quad . \quad . \quad . \quad (15)$$

In the compressor tested the constant k was found to have a value of 0·368.

Using this equation, the b.h.p. required for any given condition can be expressed :

$$\text{b.h.p.} = V_s\eta_v\left[1\cdot07\alpha + k.v^{1.3}.d^{0.1.5}\left(1+\frac{R^2}{20}\right)\right] \quad . \quad . \quad . \quad . \quad (16)$$

Comparison of Suggested Formula and Test Results

Curves calculated from Equation (16) are plotted in Fig. 9 on which the test results

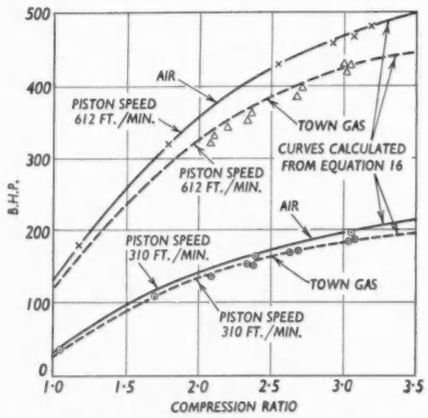


Fig. 9—Comparison of test and calculated power requirements for 12in compressor

are also shown. It will be seen that as with the volumetric efficiency calculations, there is a very good measure of agreement.

By putting $R=1$ in Equation 16 the horse-powers required to operate the compressor with atmospheric intake and discharge are obtained. These are :

Air (306 r.p.m.), 0·405 b.h.p./M.c.f.h.
Town gas (306 r.p.m.), 0·382 b.h.p./M.c.f.h.
Air (155 r.p.m.), 0·176 b.h.p./M.c.f.h.
Town gas (155 r.p.m.), 0·162 b.h.p./M.c.f.h.

The average of these is 0·281 b.h.p./M.c.f.h. which agrees with a range of 0·24 to 0·28 quoted by Gill[6].

Acknowledgments

The author would like to thank Mr. K. H. Tuson, of Messrs. Mackness and Shipley, for advice and assistance in preparing this article and the Chief Engineer, Southern Gas Board, for permission to publish the results of tests on the Board's compressors.

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[2] Gill, *Gas and Air Compression*, John Wiley and Sons, page 51.
[3] Gill, *Gas and Air Compression*, John Wiley and Sons, page 55.
[4] *Gas Engineers Handbook*, McGraw-Hill, page 761.
[5] *Engineering Data Book*, Natural Gasoline Supplymen's Association, page 33.
[6] Gill, *Gas and Air Compression*, page 57.

APPENDIX 1

Method of Estimating the Volumetric Efficiency of a Compressor Running on Town Gas

From Equation (1) the following is derived:

$$V_c = \frac{1-\eta_v}{R^{1/n}-1} \quad . \quad . \quad . \quad . \quad . \quad (17)$$

The value of the volumetric efficiency on air for a given compression ratio is obtained experimentally and inserted in the right-hand side of the Equation (17). It is assumed that the re-expansion is adiabatic and so $n=1\cdot4$. The value of V_c thus obtained is known as the "effective clearance" and is usually about 40 per cent greater than the true clearance. The volumetric efficiency on town gas is then calculated from Equation (1) by using for the clearance volume the value obtained for the "effective clearance" and the γ value of Town gas.

It will be seen that no account is taken of any change in gas density, although this will affect the leakage past the piston and valves. It is considered that the use of this method for obtaining estimated volumetric efficiencies on town gas may give rise to results which are as much as 5 per cent high.

APPENDIX 2

Tests on 12in Stroke, Single-Stage, Double-Acting Compressor Pumping Town Gas

Fig. 10 shows schematically the layout of the plant and equipment used for site tests. From the retort houses the "make" was measured by Connersville meters and taken to a 2,500,000 cubic feet capacity holder. From there the gas was fed through a Dri-gas plant, to extract moisture, and a benzole extraction plant, to a compressor, driven through a gearbox by a two-speed electric motor. From the compressor the gas was passed through an after-cooler, gate valve and orifice meter to the supply mains.

Measurement Points.—Gas temperature and pressures were measured at the Connersville meters, the outlet from the holder, the inlet to and outlet from the compressor and at the orifice meter. The holder inlet pressure was also measured. The ambient air temperatures at the north and south of the holder and the temperature of the holder seal water were recorded. The specific gravity of the gas was measured by a Specific Gravity Bell just before it entered the compressor. The compressor inlet pressure was measured by a recording pressure gauge and the outlet pressure by a South Eastern Gas Board pressure gauge having an accuracy of ±0·01 lb per square inch. The Connersville meters had previously been calibrated to an accuracy of 0·02 per cent. The quantity of gas in the holder was measured by the change in holder height, each 1in being equivalent to approximately 1000 cubic feet of gas.

The orifice meter was a pressure differential meter with a distant recording dial. The limits of accuracy of this meter, as declared by the makers, were ±2 per cent, and tests had showed that it was within them.

The energy absorbed by the compressor motor was measured by an industrial kilowatt-hour meter built into the motor control panel. The efficiencies of the motor and gearbox had previously been determined at the maker's works.

Test Procedure.—All results were corrected to Standard Conditions. The condensates from the Dri-gas plant and the benzole extraction plant were measured and corrections made for the reduction in gas volume. Before the test the compressor non-return valve seating was examined and the valve loaded above the compressor outlet pressure. This was adjusted as required by a gate valve between the after-cooler and orifice meter.

The tests were divided into two series. In the first, each test at steady compressor inlet and discharge pressures lasted two hours. All readings were taken at fifteen-minute intervals. The gas flow was measured by the change in holder stock the flow into the holder and the orifice meter. In the second series, the flow was recorded by the orifice meter only.

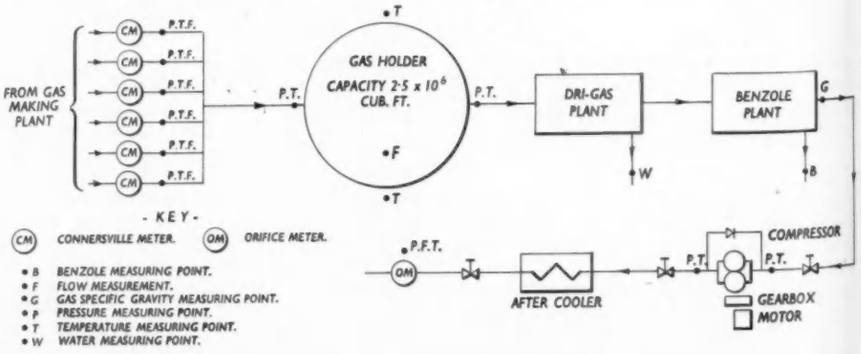

Fig. 10—Diagram of site test arrangement for 12in compressor

Test Conditions (*First Series*).—In the last test of the first series readings were within the following limits :

Nos. 1 and 2 Connersville meters	Temperature 79 deg. Fah. $\pm\frac{1}{2}$ deg. Fah.
Nos. 3 and 4 Connersville meters	Pressure +6·5in W.G. ±0·05in W.G. Temperature 87 deg. Fah. $\pm\frac{1}{2}$ deg. Fah.
Holder inlet	Pressure 7·5in W.G. ±0·05in W.G.
Holder outlet	Pressure 6·45in W.G. ±0·05in W.G.
Ambient air temperature	Temperature 55 deg. Fah. $\pm\frac{1}{2}$ deg. Fah.
Holder seal water	Pressure 5·85in W.G. ±0·05in W.G.
Barometer	54 deg. Fah. ±3 deg. Fah.
Compressor	Temperature 70 deg. Fah. $\pm\frac{1}{2}$ deg. Fah. 30·01in Hg. ±0·01in Hg.
	Discharge pressure 30. p.s.i.g. ±0·01 p.s.i.
	Inlet pressure 5·3in W.G. ±0·2in Hg.
	Compression ratio 2·997 ±0·004.
	Gas Discharge temperature 205 deg. Fah. ±5 deg. Fah.
Gas specific gravity	0·470 ±0·010 (mean 0·472).

Test Results (*First Series*).—With the compressor running at 306 r.p.m. and gas having a gamma value, calculated as shown in Appendix 3, of 1·37, the following readings were obtained during the two-hour run :

Total gas produced		917,000 cubic feet
Increase in holder stock		452,000 cubic feet
Gas taken from holder		465,000 cubic feet
Dri-gas plant loss	1,200	
Benzole plant loss	9,600	
	10,800 cubic feet	
Volume of gas pumped		454,200 cubic feet

This is equal to a flow of 227,100 c.f.h. and as the orifice meter on the outlet side of the compressor recorded, after the necessary corrections had been made, a flow of 231,000 c.f.h., the output of the compressor was taken as 230,000 c.f.h. This is equivalent to a volumetric efficiency of 0·714. The figure for air under the same conditions was 0·756 or 5·9 per cent higher. The power, corrected to standard conditions, absorbed at the compressor coupling was 430 b.h.p. or 1·87 b.h.p./M.c.f.h. compared with 1·92 b.h.p./M.c.f.h. on air.

Test Results (*Second Series*).—It was not possible to carry out such elaborate tests at other compression ratios so further readings in which the flow was measured by the orifice meter only were taken with outlet pressures down to 10 p.s.i.g.

APPENDIX 3

Calculation, in accordance with Appendix A to B.S.2009 : 1953 " Acceptance Tests for Turbo-Type Compressors and Exhausters," of γ value of Town's gas having the following properties :

Constituent gases	Percentage by volume	C_v	$V(C_v)$
CO_2	3·3	6·80	22·4
O_2	1·1	5·02	5·5
C_nH_m	2·9	8·0	23·2
H_2	51·4	4·89	251·0
CO	15·1	4·97	75·0
C_2H_6	2·5	8·0	20·0
CH_4	14·4	6·49	93·5
N_2	9·3	4·97	46·2
	100		536·8

$$\gamma \text{ mix} = 1 + \frac{198 \cdot 6}{V_1(C_v)_1 + V_2(C_v)_2 + \ldots + V_n(C_v)_n}$$

where V_1 &c. = Percentage by volume of constituent gases.
$(C_v)_1$ &c. = Specific heat at constant volume in B.Th.U. deg. Fah./lb mole of constituent gases.

Hence

$$\gamma = 1 + \frac{198 \cdot 6}{536 \cdot 8} = 1 \cdot 37.$$

Refractory Concrete for Deflecting Rocket Exhaust Gases

G. LANDON, B.Sc., Ph.D.,* and R. W. THACKRAY, A.I.Ceram.

In large rocket test installations where static firings are carried out, it is necessary to protect the base of the structure and the foundations from the hot, high-velocity exhaust gases. Flame deflectors made from refractory concrete are to be used in future installations. The concrete is expected to erode under these very severe conditions at rates of up to 0·050in per second of firing time, but tests have shown that repairs can be carried out conveniently and successfully.

TEST bed firings of small liquid-propellent rocket engines—say, up to 10,000 lb. thrust—are usually carried out with the engine in a horizontal position. The disposal of the exhaust gases then presents no problem. The test bed is arranged so that the emerging gas stream moves without interruption across a suitably large open space, without causing damage to any part of the site structure.

Larger engines, however, are tested in a vertical position with the exhaust gases moving in a downward direction. This arrangement is dictated by the high mass flow rate of propellents, which is of the order of 500 lb per second for an engine of 100,000 lb thrust. On this scale, the accidental release of unburned propellents could have serious consequences, since these are likely to form a highly sensitive explosive mixture, and the vertical arrangement is therefore chosen owing to the relative ease with which instantaneous sluicing can be carried out. However, because of the high temperature and velocity of the exhaust gases, some sort of flame deflector now becomes necessary in order to protect the base of the structure, and the foundations, from flame erosion.

The commonest type of flame deflector takes the form of a bucket, or scoop, deflecting the exhaust gases through an angle varying between 30 deg. and 90 deg. according to the nature of the surrounding terrain. This type is used in test sites like the one shown in Fig. 1. The flame-deflecting surface is usually of boiler plate, water cooled from underneath, and protected against excessive temperature gradients by a surface film of water ejected through carefully positioned holes drilled in the plate itself. The design of such a deflector is complex, the cost of manufacture is high, and the delay and expense resulting from accidental damage can well be appreciated. Because of this, and because of the cost of obtaining an adequate supply of water in desert areas such as are used for rocket flight trials (up to a ton a second is used during a firing), an alternative method of deflecting rocket exhaust gases has been investigated.

Tests have indicated that a satisfactory deflector, needing no water cooling, can be made from refractory concrete consisting of high-alumina cement with a suitable aggregate. Such concrete needs no preliminary kiln-firing and can therefore be cast in position as a monolithic structure. Ciment Fondu† and Secar 250†, for example, have each proved satisfactory when used with an aggregate of crushed firebrick. Other types of deflector have been considered, but these are generally thought to be unsuitable. For example, an uncooled steel " heat sink " would impose a severe limit to the duration of test firings (see Fig. 2). Concrete containing Portland cement has been considered as a deflecting material, but this has been known to erode to a depth of 10ft during a firing of twenty seconds under relatively mild conditions.

Finally, it is not known whether or not kiln-fired refractory bricks or slabs have ever been used successfully in large test sites, but certainly cases of failure have been reported. It seems that the main cause of trouble is the build-up of stagnation pressure underneath the slabs, which lifts them into the high velocity gas stream. Once a single slab is dislodged, from whatever cause, the effect on the remaining slabs is likely to be immediate and catastrophic.

In the present experiments, specimens of various types of refractory concrete were placed obliquely in the exhaust gases of a liquid-oxygen/kerosene engine of 3500 lb thrust, in which the fuel : oxygen ratio was about 2·4 : 1. The combustion chamber pressure was 350 lb per square inch gauge, the theoretical combustion temperature 3400 deg. K and the corresponding exhaust velocity about 7000ft per second. The distance from the engine to the centre of the area of flame impingement on the specimen was varied between 2ft and 12ft and the angle of flame impingement was generally 30 deg. The most suitable concretes, containing crushed firebrick aggregate, eroded by fusion only, at linear erosion rates of up to 0·040in a second. Other concretes tested were less suitable, although concrete containing an aggregate of pure fused alumina can be used where the deflector is in the form of a single plane surface. It erodes at up to 0·020in a second in the area of flame impingement, but higher erosion rates will occur downstream if the deflecting surface is curved or multi-planar. This is because this material does not erode entirely by fusion. Solid particles are removed from the surface in the area of flame impingement, and these exert a severe scouring action downstream if any further deflection of the gas stream is attempted.

Perhaps it is surprising that castable refractories should be able to withstand such severe conditions because, although they are well known for their high spalling resistance, heating rates in normal applications are very much lower. On first heating the placed concrete, the combined water which forms the hydraulic bond is released progressively up to 900 deg Cent. (above which temperature a ceramic bond is formed). In the present application the concrete is not preheated in any way, and it might be expected that the sudden release of the combined water could cause disruption of the material. This tendency has certainly been encountered, but it has been overcome by using a suitable aggregate and by selecting a suitable aggregate/cement ratio. The released steam then escapes at low pressure into the material below the heated surface, without causing any mechanical damage.

* Now with British Titan Products Co. Ltd.

† Manufactured by the Lafarge Aluminous Cement Company.

Technical Contributors Section (*continued*)

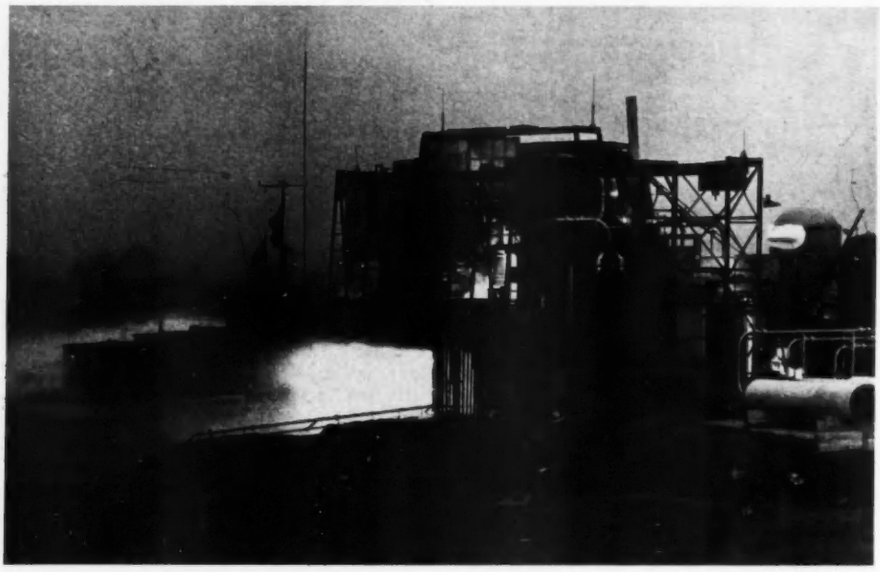

Fig. 1—A large test installation. The engine of 100,000 lb thrust burns kerosene and liquid oxygen and fires downwards onto a water-cooled steel deflector. Flame temperature is about 3000 deg.Cent.; gas velocity about 7000ft per second

Materials Used

The aggregate used in the tests was good quality crushed firebrick containing 40-42 per cent combined alumina, and generally conforming to the specification recommended for conventional refractory concrete.[1, 2] The cements used were Ciment Fondu and Secar 250, the properties of which have been described in detail elsewhere.[3, 4] The former is a grey high alumina cement containing about 15 per cent iron oxides and 5 per cent silica, whereas the latter is a pure white calcium aluminate cement containing only about 1 per cent total impurities. Hereafter, for the sake of brevity, these are referred to as "grey cement" and "white cement" respectively. The melting points of these cements and the approximate average melting points of their respective concretes are as follows:

Grey cement	1310 deg. Cent.
Firebrick/grey cement...	1540 deg. Cent.
White cement	1650 deg. Cent.
Firebrick/white cement	1640 deg. Cent.

Aggregates graded from $\frac{3}{8}$in down and from $\frac{1}{8}$in down were chosen. Gradings exceeding $\frac{3}{8}$in were avoided owing to the possibility of failure of the larger particles by thermal shock. The "fines" content of the aggregate (passing a 100 B.S. sieve) was between 5 and 10 per cent, rather than the 15 per cent usually recommended. Mix proportions are given in Table I. These mixes are used generally for sections 3in thick or more.

Table I—*Mix Proportions.*

Material	Composition, weight percentage	
	Mix A	Mix B
Crushed firebrick, $\frac{3}{8}$in.–$\frac{1}{8}$in ...	34	35
Crushed firebrick, $\frac{1}{8}$in dust ...	41	42
Grey cement	25	—
White cement	—	23

For thinner sections, minor repairs, &c., a mortar consisting of fine aggregate ($\frac{1}{8}$in-dust) and cement in the ratio of about 3 : 1 by weight was found to be satisfactory—a somewhat leaner mix than is generally used.

The other material which gave good results under certain conditions consisted of an aggregate of pure fused alumina with white cement in the ratio 8 : 1 by weight. The alumina is graded $\frac{1}{8}$in dust and should contain not more than 15 per cent fines. Similar results are obtained using instead brown corundum, which contains about 5 per cent. impurities, provided that the particle shape is conducive to good consolidation. Other aggregates which were tried, but which were found to be unsatisfactory, were silicon carbide, zircon sand, Alag (a synthetic aluminous aggregate) and limestone.

Experimental Details

Preliminary experiments were carried out on a number of materials, cast on a vibrating table in moulds to form slabs 18in by 6in by 3in. These were placed 2ft from the engine at an angle of 30 deg. to the flame axis as shown in Fig. 3. For each material, one slab was subjected to successive firings of five seconds and another to one or two firings of twenty seconds duration. Results were always similar in the two cases. Maximum linear erosion was measured after each firing (see Fig. 4). The effect of varying the aggregate/cement ratio was studied in most cases, and the water/cement ratio was kept low. Attention was paid to the particle size distribution of the aggregates and of the final mixes, and this was related to the measured bulk density, strength and porosity.

The most successful concretes were those containing crushed firebrick, which was among the least refractory of the aggregates tried. These concretes were the only ones to erode solely by fusion. Concretes made with pure fused alumina or brown corundum eroded partly by fusion, partly by removal of solid particles from the surface. They in fact eroded more slowly in the area of flame impingement, but later tests revealed serious erosion downstream. In all the other cases, material was removed from the surface almost entirely in the solid state, and the erosion rates were very high. Silicon carbide failed owing to an apparent lack of adhesion between the aggregate and the cement. Zircon sand had a poor particle size distribution. Alag failed owing to the poor thermal shock resistance of the individual aggregate particles, while limestone failed, as expected, through thermal decomposition of the aggregate.

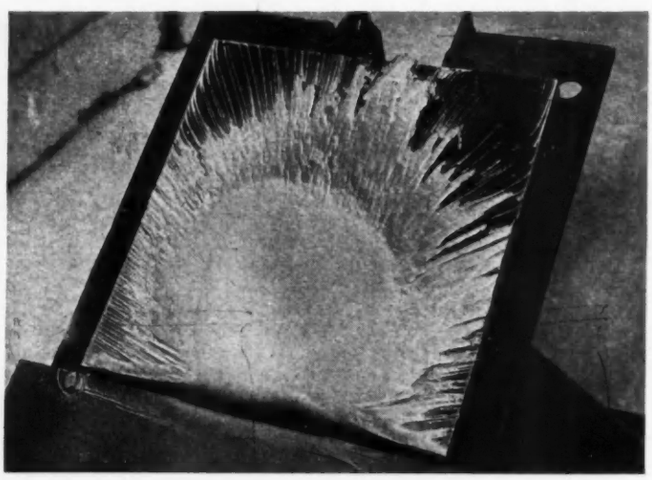

Fig. 2 (Left)—A $\frac{1}{4}$in mild steel plate exposed to the efflux of a 3500 lb thrust engine for six seconds Fig. 3 (Right)—Preliminary erosion experiments on concrete specimens 18in by 6in by 3in. The horizontal dark streak is cooling water from the engine, ejected to one side

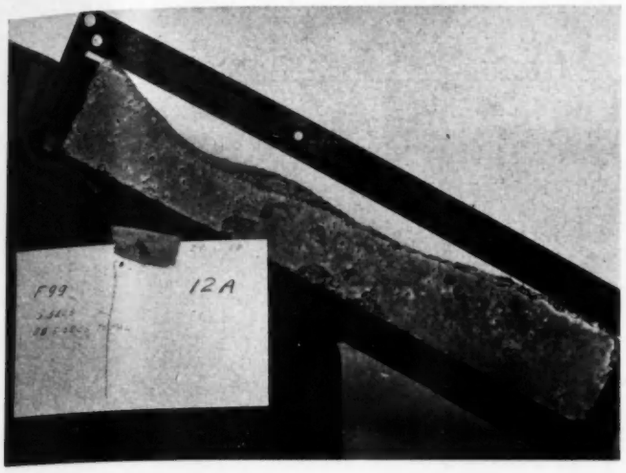

Fig. 4—After firing. The straight-edge lies in the plane of the original surface, from which maximum linear erosion is measured

In most cases, a factor contributing towards failure was the steam released from the concrete, which tended to blow off thin flakes of material, or spalls, from the surface (see Fig. 5). This effect could be reduced by lowering the cement content of the concrete while maintaining the same amount of water, thus simultaneously reducing the amount of combined water present and increasing the porosity of the air-dried concrete. However, this procedure also lowered the strength of the material, and only gave satisfactory results with pure fused alumina and brown corundum.

It was not found necessary to reduce the cement content of the concretes containing crushed firebrick, and this is attributed to the high porosity of the aggregate itself and the correspondingly higher overall porosity of the concrete. The good resistance to thermal shock of the individual firebrick particles is also due in part to their porosity. Even with firebrick as an aggregate, insufficient attention to the grading of the aggregate led to poor results. Again, poor consolidation of the concrete due to inefficient vibration gave poor resistance to erosion. On the other hand, proper attention to these details gave dense concrete with a relatively low water : cement ratio and hence a high strength, and the erosion behaviour in the rocket flame was then consistently good.

Fig. 5—Specimen which has spalled during five seconds of firing. Lightest areas show where spalling has occurred immediately after shut-down. Partially fused surface is blown off in thin flakes by action of steam released within concrete

Confirmatory Tests

It was first required to know whether a conventional expanded metal key would hold the concretes in position, since in the earlier tests the specimens had been clamped to a test stand. Slabs 18in square were therefore cast onto steel backing plates, with a key of this type fixed 1in above the plate surface. The backing plate formed the base of a mould (Fig. 6) from which the sides were stripped after the slab had been cured. During subsequent tests, this arrangement was completely successful.

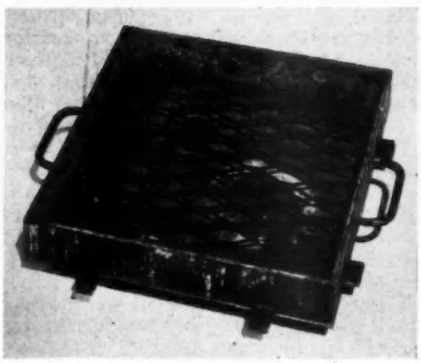

Fig. 6—Mould for casting slabs keyed to base plate with expanded metal

Repairs were carried out to some of the slabs after they had been eroded in the rocket flame. The fused surface of the concrete was chiselled off, the sides of the mould were reconnected to the backing plate, and fresh concrete was placed into the cavity, and compacted by vibration, after the underlying material had been soaked with water. The thickness of the repairs varied between ¼in and 2in. During subsequent tests, no case of failure occurred and the repairs were considered to be completely reliable.

Another test which was repeated frequently was the spraying of water onto the hot surface of the concrete immediately upon shut-down of the engine. In no case was any significant damage caused, either at the time or during subsequent firings.

Using 18in square slabs made from the successful materials, various exploratory tests were carried out, leading finally to the arrangement shown in Fig. 7. This test was done to investigate possible scouring effects downstream of the flame impingement area by material eroded upstream—effects which could be important if a deflector has to be built in the form of a curved or multi-planar surface. The upstream slab was placed at 30 deg. to the flame axis, 4½ft from the engine, while the downstream slab, of the same material, deflected the flame through a further 30 deg. Two firings of twenty seconds each were carried out on slabs of firebrick/grey cement (Fig. 8), firebrick/white cement and alumina/white cement concretes. These tests were done after the slabs had been air-dried at room temperature for seven days after placing. The behaviour of the firebrick/grey cement and the firebrick/white cement concretes was similar, though an improvement was observed using the latter. The test was repeated on firebrick/grey cement and the alumina/white cement after the slabs had been repaired. Again, the slabs were air-dried for seven days, but this time were soaked in water for twenty-four hours before testing. Finally, new slabs of these two concretes were made and were tested twenty-four hours after the concrete had been placed, and while the material was still saturated with water.

Values for the maximum rates of linear erosion measured in these tests are given in Table II, which illustrates two important facts. First, alumina/white cement erodes more slowly in the area of flame impingement, dry or wet, than firebrick/grey cement concrete. Both erode more rapidly when freshly placed, and alumina white cement is the worse from this point of view. Secondly, both concretes erode more rapidly on the downstream slab but with alumina white cement the effect is more pronounced, especially when wet or when freshly placed. From these tests it is concluded that alumina white cement should only be used where the deflecting surface can be made in a single plane, and that firebrick grey cement should always be used where this is not possible.

In these tests, the slabs were weighed after each firing. From the loss in weight and the measured bulk density, values were calculated for the average rate of erosion over the area of each slab (Table III). These

Table II—*Rates of Maximum Linear Erosion, in Thousandths of an Inch per Second, on Two Slabs* (a *and* b). a *is Upstream at* 30 *deg. to the flame;* b *is Downstream at* 60 *deg. The quotient* b/a *Gives an Indication of the Scouring of* b *by Material eroded from* a. (*See Fig.* 8.) *Distance from Engine is* 4½*ft, or* $0{\cdot}076\sqrt{F}$.

Concrete	Concrete dry, seven days after placing			Concrete wet, seven days after placing			Concrete wet, twenty-four hours after placing		
	a	*b*	*b/a*	*a*	*b*	*b/a*	*a*	*b*	*b/a*
Alumina/white cement	17	30	1·8	12	35	2·9	36	103	2·9
Firebrick/grey cement	27	40	1·5	24	38	1·6	32	35	1·1
Firebrick/white cement	31	36	1·2	25	36	1·4	—	—	—

Table III—*Corresponding Average Rates of Erosion, Calculated from Weight Loss and Density of Slabs.*

Concrete	Concrete dry, seven days after placing			Concrete wet, seven days after placing			Concrete wet, twenty-four hours after placing		
	a	*b*	*b/a*	*a*	*b*	*b/a*	*a*	*b*	*b/a*
Alumina/white cement	6	8	1·3	8	15	1·9	13	20	1·6
Firebrick/grey cement	14	14	1·0	14	16	1·2	15	17	1·1
Firebrick/white cement	11	13	1·1	11	14	1·3	—	—	—

Technical Contributors Section (*continued*)

Fig. 7—Confirmatory test on two slabs, 18in square

Fig. 8—Mix *A* after total of forty-four seconds firing

values afford a more accurate means of comparison than the rates of maximum erosion, although the latter are more important from a practical point of view. Further tests on more massive specimens have, in fact, shown that alumina/white cement can erode excessively when wet, even though well aged, suggesting possibly that the larger bulk inhibits the escape of steam. Similar tests on firebrick/grey cement did not show this effect, and there seems no reason why this material should not be used on a large scale when wet, if this is either convenient or necessary.

From the point of view of downstream erosion, the superiority of the firebrick grey cement is doubtless due to the fact that the material is eroded entirely in the liquid state. The alumina white cement erodes partly by fusion, but even in the absence of spalling due to internal steam pressure, failure of individual aggregate particles by thermal shock results in the loss of material in the solid state. The fragments of solid alumina appear to exert a scouring action on the material downstream—an effect which could be seriously cumulative where the exhaust gases are to be deflected through a large angle.

Finally, brief mention may be made of tests carried out at a greater distance from the engine in the region where the exhaust gases become subsonic. Slabs of concrete 3ft square and 6in thick were placed at an angle of 45 deg., 12ft from the engine. Firings of about thirty seconds duration were carried out on each slab. After a total of 300 seconds of firing, alumina/white cement had eroded to a depth varying between $\frac{1}{8}$in and $\frac{1}{4}$in. Firebrick/grey cement eroded to a depth of $\frac{1}{2}$in in 260 seconds, while firebrick/white cement eroded to a depth varying between $\frac{1}{4}$in and $\frac{1}{2}$in in the same time. Erosion rates could not be measured more accurately than this owing to the undulating nature of the eroded surface. Measurement by weighing was impracticable because the slabs were too heavy.

Choice Between Grey and White Cements

Tables II and III do not show unequivocally that white cement gives a better performance than grey cement, though this would be expected from the higher melting point of the former. In fact, white cement melts at a somewhat higher temperature than the firebrick aggregate, and the aggregate particles should therefore be less likely to become dislodged before melting. Table III, which gives the more reliable results, shows that white cement reduces the rate of erosion by 10 to 30 per cent. Table II shows little difference between the cements, and does actually show a reverse trend in the first column. This trend may be real, though it should be borne in mind that the rate of maximum erosion is more sensitive to slight variations in the experimental conditions.

Ultimately, the choice depends on economics. The cost of materials in firebrick/white cement concrete is about double the cost for firebrick/grey cement. This ratio is considerably reduced by the time the materials have been delivered to a desert site. If the cost of placing is then included, it is only 5 or 10 per cent more expensive to use white cement. Thus, if a decrease of 10 per cent or more is obtained in the rate of erosion, it is preferable to use white cement. A further point to be considered is that, when the deflector has eroded to the extent that repair becomes necessary, only a fraction of the original material needs to be replaced, since maximum erosion occurs only down the middle of the deflector. It is therefore concluded that the most economic procedure is to construct the deflector initially from firebrick/grey cement, and to carry out subsequent repairs using the same aggregate with white cement.

Scaling Procedure

Stagnation temperature, stagnation pressure and gas velocity in a rocket flame each vary according to the distance from the engine—though not linearly—owing to dissipation of energy by turbulent mixing of the gas stream with the atmosphere, and at a certain distance from the engine the flame becomes sub-sonic. Consequently, the rate of erosion of a deflector depends upon the distance between the engine and the area of flame impingement. In order that the results of experiments obtained using a small engine should have practical value, it is necessary to know how conditions in the flame compare with the conditions obtaining in the flame of a larger engine. If the propellents are the same in each case and the combustion conditions (temperature and pressure) are likewise the same, the scaling rule is simple.

Let F and F' respectively be the thrust in pounds of two engines, and let two points lie, one on the axis of each flame, at distances d and d' from their respective engines. Then the temperatures, pressures and gas velocities at the two points will be similar provided that

$$\frac{d}{\sqrt{F}} = \frac{d'}{\sqrt{F'}}$$

Since the thrust of the engine used in the present tests was 3500 lb and the principal experiments were carried out with specimens at 4ft 6in and at 12ft from the engine, the corresponding distances for any other engine of thrust F will be $4{\cdot}5\sqrt{F}/\sqrt{3500}$ and $12\sqrt{F}/\sqrt{3500}$, i.e. $0{\cdot}076\sqrt{F}$ and $0{\cdot}203\sqrt{F}$ respectively.

Where a comparison is required with an engine using different propellants, the calculations are complex and generally less reliable. In such a case it is preferable that check experiments should be carried out.

Heat Radiated After Firing

If the deflector is to be placed relatively close to the engine, there arises the possibility of damage to the engine, or to other parts of the installation, by heat radiated from the concrete after shut-down. To estimate the amount of heat it is necessary to know the temperature distribution below the surface of the concrete. Measurements from thermocouples embedded in some of the concrete specimens gave reasonable agreement with calculations from equations derived by Askew and Thackray (private communication).

The material is considered as a semi-infinite solid whose plane boundary is heated instantaneously to a temperature T_f (the melting or softening temperature) at which it is eroded at a constant rate by the hot gas stream. For materials of the kind

under consideration, a virtual steady state (relative to the eroding surface) is rapidly reached. The temperature distribution is then simply :

$$Tx = Ta + (T_f - Ta)e^{\frac{-xU}{k}} \quad . \quad . \quad (1)$$

where Tx is the temperature (deg. Cent.) x cm below the eroding surface, Ta is ambient temperature, U is the rate of erosion in centimetres per second and k is the thermal diffusivity in square centimetres per second. For example, in the case of concrete eroding at 0·025in a second, this steady state is practically reached within one second of the start of firing.

For concrete which is not eroding, but which is nevertheless heated, it is again assumed that the surface temperature rises instantaneously to T_f. This condition obtains approximately at the edge of the flame impingement area. The temperature distribution now varies with the firing time, t :—

$$Tx = Ta + (T_f - Ta)\,erfc\left(\frac{x}{2\sqrt{kt}}\right) \quad . \quad . \quad . \quad (2)$$

Typical temperature distribution curves are shown in Fig. 9, from which the total

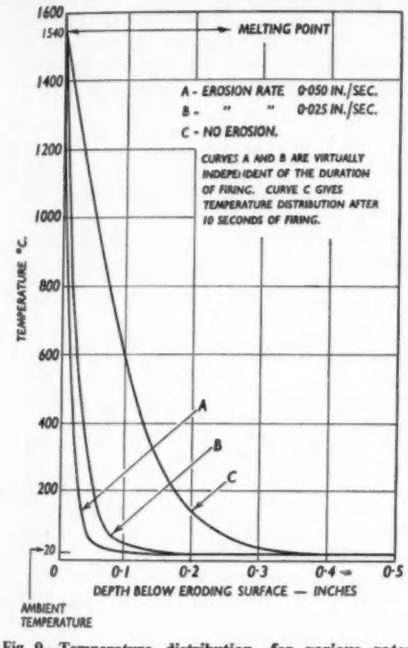

Fig. 9—Temperature distribution, for various rates of erosion, below the surface of a firebrick, brown cement deflector

heat absorbed can be calculated by integration, assuming a mean value of 0·3 calorie per gramme for the specific heat of firebrick/grey cement which has not previously been heated, and 2·0 for the density. T_f is taken to be 1540 deg. Cent. and k to be 0·004 square centimetre per second.

In estimating the total heat, further allowance has to be made for any molten concrete which may be present on the surface at shut-down. For concrete which is not eroding, such a surface film may be quite thick (say, 0·1in), or it may be entirely absent. For concrete eroding at 0·025in to 0·050in a second, however, the liquid film is usually about 0·01in thick. A rough estimate of the heat contained in this film has been made, assuming its mean temperature to be $T_f + 250$. Other values assumed are 2·5 for the density and 0·5 for the specific heat of the liquid, and 160 calories per gramme for the latent heat of fusion. Results for the total heat radiated from firebrick concrete are given in Table IV. Although

TABLE IV—*Estimated Heat Radiated from Firebrick/Grey Cement in Cooling to 100 deg. Cent. after a Firing.*

Erosion rate, inches per second	0·05	0·025	Zero	Zero	Zero	Zero
Firing time, seconds	Any	Any	5	5	10	10
Thickness of molten surface film, inches	0·01	0·01	Zero	0·1	Zero	0·1
Total heat radiated (B.Th.U. per square foot) in cooling to 100 deg. Cent.	240	320	500	2,100	700	2,400

very approximate; these figures will give some indication of the magnitude of the effect, and will show roughly how much cooling may be necessary at the end of a firing to absorb all the heat present.

The time taken to cool is short. Rough calculations based on Stefan's radiation law, neglecting convective cooling, show fair agreement with visual observation. Concrete eroding at 0·025in to 0·050in a second cools to 1000 deg. Cent. in about five seconds after shut-down, and to 100 deg. Cent. in about five minutes, while concrete which is not eroding cools about twice as slowly as this after a five second firing and three times as slowly after a ten second firing.

Conclusions

Firebrick/grey cement is a suitable material for deflecting the exhaust gases of liquid propellant engines and should prove successful in large rocket test installations. At a distance of about $0{\cdot}076\sqrt{F}$ ft from the engine (F being the thrust of the engine in pounds) the rate of erosion should not be greater than 0·050in a second where liquid oxygen and kerosene are the propellants used. At a distance of $0{\cdot}203\sqrt{F}$ ft, the erosion rate should be about 0·002in a second.

When repairs become necessary, the grey cement should be replaced by white cement. The higher cost of the latter should be offset by a decrease in the subsequent rate of erosion of between 10 and 30 per cent.

Pure fused alumina or brown corundum could be used with white cement where the flame deflector has a single plane surface, and where it can be kept dry. The erosion rate should not exceed 0·030in a second at $0{\cdot}076\sqrt{F}$ ft, or 0·001in a second at $0{\cdot}203\sqrt{F}$ ft.

Owing to the severe conditions of use, careful site control is recommended to ensure good consolidation of the concrete with the lowest possible water/ cement ratio, and the usual curing procedure for high-alumina cement should be followed. The deflector can be made as a monolithic structure without expansion joints and can be secured to the underlying structure by means of an expanded metal key. Repairs can be carried out after the concrete has eroded, provided the fused surface is first removed, and no special key is necessary between the old and the new material.

At the end of a firing, between 200 and 3000 B.Th.U. of heat may be radiated from each square foot of concrete, depending upon the rate of erosion. This heat can be absorbed, without damage to the concrete, by spraying with water immediately after the firing.

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Chemical Plant Repairs Using Epoxy and Polyester Resins

By H. HUGHES, B.Sc., A.P.I., and A. F. HALL

The use of epoxy and polyester resins for the repair of chemical plant is described. The resins with additions of powdered fillers or reinforcing agents, e.g. glass cloth, have been used successfully for a wide variety of applications ranging from small repairs to pump casings to the renewal of 1500*-cubic-metre tank bottoms. Resin repairs can be made quickly* in situ *by plant maintenance personnel, thus avoiding delays involved in movement of the affected plant to workshops and the use of specialist labour. Because the resins are cold-setting, repairs can be made in fire-risk areas where welding would involve special precautions.*

IN the running of chemical plant, even small losses of metal from process equipment by corrosion, erosion or abrasion can have serious consequences, especially if the attack is localised, i.e. if pitting occurs. Cracks and the development of porosity, e.g. in castings, are similar sources of trouble. Various repair methods are available according to the type of job and the permanence required from the repair. These include welding, metal spraying and electro-deposition, which replace the wasted metal, and the application of various protective linings, e.g. of bricks or sprayed concrete. These methods are often difficult and expensive to carry out, involving plant shut-down time and the use of specialist labour. Occasionally *in situ* repairs can be made by the ordinary maintenance workers and substantial savings can thus be obtained ; but the methods available to them are few except for making the most temporary of repairs, e.g. wrapping a burst water pipe with grease-impregnated tape. For some years, phenol formaldehyde or furane resins, bitumen and rubber latex/ hydraulic cement compositions have been used for *in situ* repair work, but their success has been limited for various reasons—especially difficulty of handling and poor adhesion in the case of the resins and inadequate chemical resistance with the bitumen and latex compositions. More recently attention has been given to the use of epoxy and polyster resins, especially the former ; these adhere better to various surfaces, including concrete, ceramics and wood, as well as to ferrous and other metals, and are easier to use and more reliable in their setting properties. Like most other resins they may be "cold setting" so that in addition to their other advantages they permit repairs to be made in fire-risk areas where welding would not be permitted. Simple techniques have now been developed

Technical Contributors Section (*continued*)

for *in situ* repairs of various kinds and a number of plant applications have been made with considerable financial savings.

Epoxy and Polyester Resins

Epoxy resins are condensation products of epichlorhydrin and a polyhydric phenol, usually diphenylol propane. The liquid resins can be made to set by the action of heat and some curing agent, which may be a urea or phenol-formaldehyde resin, a fatty acid or acid anhydride ; some curing agents, e.g. organic nitrogen compounds especially amines and amides, allow the resins to set at normal temperatures.

The polyester resins are made from polyhydric alcohols, e.g. propylene glycol, and mixtures of unsaturated and saturated dibasic acids, e.g. maleic and phthalic acids. The liquid resins after mixing with some other unsaturated compound, e.g. styrene, and a peroxide catalyst set at elevated temperatures ; if an accelerator, usually a cobalt salt, is added setting occurs at normal temperatures.

Originally developed for the low pressure moulding of resin/glass fibre radomes for service aircraft, the polyesters are well known in the form of glass fibre laminates for car bodies, boats, furniture and corrugated roof sheets. The epoxy resins because of their higher price have found more specialised uses where their superior adhesion to surfaces is required. Although some epoxy resin is used for high quality laminates, the main applications are as surface coatings, adhesives, cements and casting resins, e.g. for the " potting " of electrical components. Chemical plant process equipment such as pipes and vessels is now being made from high quality epoxy and polyester resin laminates.

Adhesion.—Epoxy resins and cements are outstandingly good adhesives. Lap joints in shear give joint strengths of about 2000 lb per square inch with aluminium, asbestos board, ceramics including glass, concrete, carbon, magnesium alloys, rubber and wood. Adhesion to zinc, cast iron, stainless and mild steels and nickel is somewhat less satisfactory, but no better cold-setting adhesive] for these metals is known. Copper, brass and lead are difficult and satisfactory adhesion cannot be obtained unless a hot-setting epoxy cement is used ; these cements always give better results than the cold-setting ones. The polyester resins and cements give weaker joint strengths than the epoxies, but they are often adequate. The efficiency of the bonding depends, of course, greatly on the degree of cleanliness of the surfaces and to some extent on their roughness. For success, the surfaces must also be dry and free from dust and oil. Some materials, e.g. bricks, glass or stainless steel, are easily cleaned because they do not ordinarily carry their own corrosion products like mild steel and cast iron ; wire brushing sometimes suffices for these latter, although grit blasting is desirable where time allows. With cast iron it is also important to see that graphitised areas are cut away.

Chemical contamination of surfaces is more difficult to deal with. Traces of some compounds, especially phenols, phenol-formaldehyde resins, sulphur, rubber, copper and carbon black, may completely inhibit the setting of polyester cements. Where these have been used, the polyesters may not be suitable even though apparently effective cleaning methods are used, e.g. grit-blasting. Epoxy cements are much less sensitive to inhibitors ; water is the most dangerous.

Temperature.—The effect of increasing temperature on polyester and epoxy cements is to soften them and reduce the bond strength; this occurs significantly in the region 80 deg. to 100 deg. Cent. with the types used in this repair work but special kinds are available which are more heat resistant. Generally, however, none of them is suitable for prolonged use above about 140 deg. Cent., but, where stresses are low, the filled cements may be used at 100 deg. Cent. The effect of sub-normal temperatures is to make the cements more brittle, although the bond strength may not be affected.

General Repair Methods

The materials and methods used for repair work vary according to the type of job but always involve mixing the resin, epoxy or polyester, with the appropriate setting agents. This gives a clear liquid which may be used as a paint, as an adhesive or for filling small cracks or areas of porosity ; cracks in and adjacent to welds in working tanks made of chromium/nickel austenitic steels have been filled in this way. Powdered or fibrous fillers and then setting agents are added to the resins to give gap-filling cements, which may be thin enough to be applied with a stiff brush or so thick that they are of putty consistency ; intermediate thicknesses are more often used and application is with a trowel. The brush-applied cements are used for filling cracks, porous areas or very small holes when the unfilled resin has insufficient " body "; they have also been used for the repair of chipped or cracked vitreous enamel coatings on process vessels and stoved-on resin coatings. The thicker cements are used to fill large holes, to replace wasted metal in substantial thicknesses, e.g. up to 2in or 3in, and for rendering over deeply pitted surfaces to provide smooth finishes ; they are especially useful for making repairs to cast iron, which is very prone to deep pitting and loss of metal by " graphitisation." Because the cements set chemically, i.e. without the necessity for solvent to evaporate, most deep holes can be filled in one operation, although, unless special precautions are taken, cement in thicknesses greater than about 6in may develop internal cracks owing to the heat evolved during setting. Sometimes it is desirable to use a fabric instead of or in addition to the filler in the resin. Fabric made from glass fibre, either woven or as random mat, or a synthetic fibre is preferable, although in emergencies cloth of any kind and even wire netting can be used. The fabric is used to improve the mechanical properties, especially tensile strength, of the cement, to hold thick sections in place during setting or to provide support for the cement during its placing over gaps. Reinforcement with fabric is especially useful when repairs have to be made on the outside of pipes ; the resin or cement-impregnated fibre can be wrapped around the pipe and pulled tightly down, when it can be held in place and reinforced by metal clips if necessary.

Used with fabric, the repair material becomes in effect a glass or other fibre laminate and some repairs, to perforated thin steel for example, become lining processes ; similarly, if large areas are covered with renderings of the filled cements without fibre, these too may be regarded as easily applied alternatives, for example to rubber or brick linings.

Mechanical Properties of Repair Materials

Experience has shown that most of the applications for resin repairs do not require high mechanical strength from the cements. A typical case is the repair of iron castings in which there may be holes to be filled or areas to be built up. It is desirable, nevertheless, to arrange for repairs to be under compression rather than tension ; the limiting factor is almost always the strength of the bond between the cement and the surface

Table I—*Mechanical Properties of Repair Materials*

	Unfilled epoxy	Unfilled polyester	Silica-filled epoxy	Silica-filled polyester	Glass cloth epoxy	Glass cloth polyester
Tensile strength, 10^3 lb per square inch	8–11	8–10	5–7	1–3	20–50*	20–50*
Compressive strength, 10^3 lb per square inch	14–15	20	16–18	12	35	35
Coefficient of linear expansion, 10^{-6} per deg. Cent	90	97	60	—	10	10
Modulus of elasticity, 10^6 lb per square inch	0·5	0·5	1·0	1·0	2·5	2·5

* Varies greatly according to the type of woven cloth used. Non-woven cloth, i.e. glass mat, gives tensile strengths in the region $10–20 \times 10^3$ lb per square inch.

Table II—*Chemical Resistance of Epoxy and Polyester Cements*

Reagent (normal temperature)	Epoxy	Polyester	Reagent	Epoxy	Polyester
Acids :			Salt Solutions *N*	*R*	*R*
3 per cent Sulphuric	*R*	*R*	**Organic Compounds :**		
20 per cent Sulphuric	*R*	*R*	Acetone	*A*	*A*
50 per cent Sulphuric	*D*	*D*	Methyl ethyl ketone	*A*	*A*
70 per cent Sulphuric	*A*	*A*	Methyl alcohol	*A*	*D*
20 per cent Hydrochloric	*R*	*R*	Isopropanol	*R*	—
35 per cent Hydrochloric	*D*	*D*	n-Butanol	*R*	*R*
15 per cent Nitric	*R*	*R*	Acetone/isopropanol azeotrope	*A*	*A*
30 per cent Nitric	*A*	*A*	Ethylene glycol	*R*	*R*
85 per cent Phosphoric	*D*	*D*	Glycerol	*R*	*R*
10 per cent Acetic	*R*	*R*	Ethyl acetate	*D*	*A*
100 per cent Acetic	*A*	*D*	Carbon tetrachloride	*D*	*D*
Alkalis :			Chloroform	*A*	*A*
10 per cent Sodium hydroxide	*R*	*R*	Trichlorethylene	*A*	*A*
30 per cent Sodium hydroxide	*R*	*D*	Diethylamine	*A*	*A*
0·88 sp. gr. Ammonia solution	*D*	*A*	Cyclohexane	*R*	*R*
			Benzene	*D*	*D*
			Nitrobenzene	*D*	*A*
			Solvent naphtha	*R*	*D*
			Lubricating oil	*R*	*R*
			Aniline	*A*	*A*
			Phenols	*A*	*A*
			Petrol	*R*	*R*

R = resistant ; *D* = doubtful ; *A* = attacked.

being repaired, which is greatly dependent on the initial cleanliness of the surface ; moreover, in common with most materials the tensile strength is less than the compressive strength. Thus where time and access permit it is better for example to repair leaking tanks which work at a positive pressure from the inside and vice versa. Applications which involve bending or peel stresses are possible but require careful consideration. Typical mechanical properties for the repair materials are given in Table I ; they should be regarded as indicative only.

Chemical Resistance

The resistance of epoxy and polyester cements set at normal temperatures to various chemicals at normal temperatures is given in Table II. The ratings are based on laboratory experience and in some cases on manufacturers' literature and show that there are not many differences between the two types. Both are resistant to caustic alkalis and to mineral acids of moderate concentration.

Resistance to organic compounds varies greatly but lower alcohols, ketones chlorinated hydrocarbons and phenols are especially destructive. Slightly improved chemical resistance can be obtained by heat-curing the cements ; on the other hand any attack on the cements will be greater than indicated in the table if the chemicals are hot.

Materials Available

There is a considerable number of resin repair kits avaliable, most of which are advertised for the repair of corroded motor-car bodies. Most of them are polyesters. Others are aimed at the industrial market and may be epoxies or polyesters often filled with metal powders. These kits are very convenient, but it is sometimes desirable, especially when large quantities are required, to make up cements from materials supplied directly from the resin manufacturers.

Typical medium-thickness formulations with these are:

(*a*) Polyester	Parts by weight
Resin	100
Catalyst paste	4
Accelerator	3
Silica flour	100–250

The catalyst paste is dissolved in the resin and the accelerator then added, followed by the silica flour filler. Note that it is dangerous to mix the catalyst paste and accelerator directly together. More or less filler may be added to give the required consistency. The cement remains workable for an hour or so and sets after three to twelve hours depending on the ambient temperature ; the rate of set may be increased by the application of gentle heat, but care is necessary because the materials are inflammable. If large areas of cement are exposed, say greater than 1 square yard at a thickness of about ¼in, setting may be retarded or even prevented by loss of styrene contained in the resin ; the remedy is to cover the cement as soon as it has been spread out with "Cellophane" or polythene film, which may be stripped off later.

(*b*) Epoxy	Parts by weight
Resin	100
Hardener	10
Silica flour	100–250

Again the consistency may be varied according to the amount of filler added. This cement has working and setting times similar to those of the polyester cement, but the rate of set is less dependent on ambient temperature. There may be hazards in the handling of epoxy and polyester resins and associated materials ; advice from the manufacturers should be sought about them.

In the above formulations, the silica flour may often be replaced by another filler. Silica has the advantage of being cheap and chemically inert, but gives mixes which flow when applied in thick layers on vertical surfaces. Where this is important, thixotropic fillers may be used, e.g. some kinds of finely divided aluminium powder. Silica flour should not be used for repairs that subsequently have to be machined because it causes rapid blunting of the tools ; aluminium powder is very satisfactory for this kind of work. Trial mixes should always be made before any new filler is used because it sometimes affects the rate of set of the cements, especially the polyesters ; for example, carbon black and anatase titanium dioxide may prevent the setting of polyesters completely.

Applications

A wide variety of applications have been found for resin repairs ranging from small repair jobs to vehicle bodies to the replacement of bases in 1500 m³ tanks. Failures have been rare and although in many cases the repairs should perhaps be regarded as temporary, experience has shown that they have satisfactory permanence.

(*a*) *Polyester.*—1. One of the first applications was for the repair of cast iron water jackets cracked by frost action. Cracks up to 4in long and about $^{1}/_{32}$in wide were sealed satisfactorily with polyester resin painted on to the cleaned and dried surface and reinforced with 0·007in thick glass cloth; an overlap of about 1in was allowed around the cracks and the finished thickness of the repair was about $\frac{1}{16}$in. To get a rapid set in the prevailing cold weather, gentle heat was applied to the patch ; a rubber bag filled with hot water was found to be useful for heating.

2. Damage to the prow and stern of a small dinghy made from glass fibre/resin was made good using glass mat and cloth and resin ; the repairs are still satisfactory after four years.

3. Frequently, repairs to the bodywork of factory vehicles are necessary before repainting is done. The use of glass fibre/resin for these has now become the standard procedure ; the alternative, welding, is more expensive because it involves movement to and from the welding shop, the use of specialist labour and more work to dress the welds to a satisfactory smoothness for car finishes.

(*b*) *Epoxy.*—1. The water for a Coke-Ovens quenching tower is contained in an elevated rectangular cast iron tank. One of the panels developed a crack about 3ft long and about ¼in wide with consequent loss of water. A repair was required in the available shut-down time of only one hour. The inside surface of the tank was first dried adjacent to and in the crack with a blow-lamp and then chipped and wire brushed. A silica-filled epoxy cement was knifed into the crack and then a glass cloth/resin patch applied to the surface, allowing a 1in overlap around the crack. The tank had to be put into service before the patch had become properly set ; it was therefore covered first with "Cellophane" and then with a grease-impregnated tape to prevent contact with the warm water until setting was complete. Some small leaks of water through the crack still occurred, but were made good using the same method during the next weekly one-hour shut-down time ; this repair lasted for about three years.

2. Test holes drilled in a mild steel stack to measure its thickness were filled with silica flour/epoxy resin cement, modified with carbon black to make it thixotropic ; dilatent cements are not suitable for this kind of application because they do not stay in place during setting. Alternative methods of filling the test holes, other than temporary ones such as the use of wooden plugs, would have been difficult because of the poor access.

3. A baffle-plate that had been tack-welded during construction into an oil-separator was sealed into position completely by applying a fillet "weld" of epoxy cement. There was insufficient access for welding without dismantling and in any case welding was not permissible in the area.

Fig. 1—Corroded side branch in cast iron tank

Fig. 2—Corroded bottom branch in cast iron tank

Technical Contributors Section (*continued*)

Fig. 3—River water pump

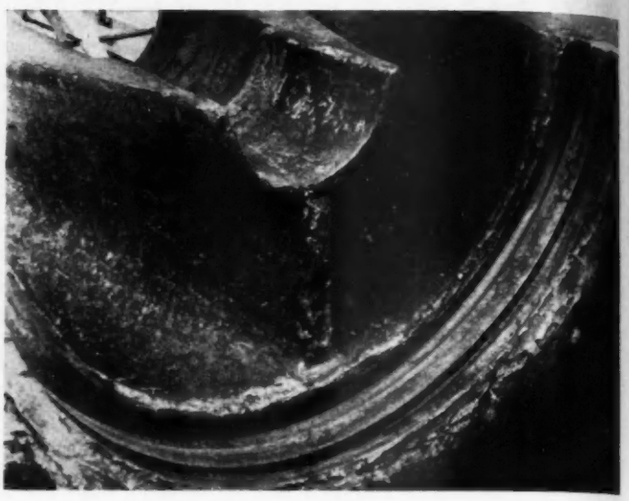

Fig. 4—River water pump ; remade sealing ring seat

4. The roofs of some storage tanks have suffered severe local corrosion and holes have developed in them. Some of the tanks are nitrogen blanketed and loss of nitrogen is an additional embarrassment. Permanent repairs by welding can be done only after elaborate precautions have been taken against fire and explosion. Fitting of plates with self-tapping screws is slow and not very effective. Patching on the outside with epoxy resin and glass cloth is quicker and more successful.

5. The body of a 6ft diameter cast iron filter drum had become severely corroded making it impossible to seat the filter plates effectively into position. The holes were filled with a silica flour/epoxy cement and, while the cement was still soft, a piece of wood (covered with polythene foil to prevent it sticking) was placed on it, moulding the cement roughly to the required profile. After the cement had set, it was dressed more accurately. This was difficult because the cement rapidly blunted the tools ; where subsequent tool work had to be done on epoxy cements, a softer filler, e.g. aluminium powder, was used instead of silica flour.

Reclaiming this filter drum by any other method would have been very difficult.

6. The body of a large rotary filter had developed large leaks close to the bearings for the drum ; the cast iron has corroded away completely over an area of about 6 square inches. The area surrounding the holes was cleaned by wire brushing and dried and then a mild steel plate with a bolt fixed in the centre pushed through the largest hole from the outside. A U-shaped piece of mild steel was fitted over the bolt on the outside with its legs resting on the filter body and the assembly was tightened up. The plate on the inside prevented the silica flour/epoxy cement that was subsequently applied from falling inside the filter body ; the plate on the outside was U-shaped to allow access for applying the cement. The cement after placing was set quickly by playing a blow-lamp over a steel plate held in near contact with it. The job was ready about six hours after the repair was started.

Other similar repairs have been done to a badly corroded cast iron tank. The side and bottom branches of one of these are shown in Figs. 1 and 2. In this case, the holes were filled with silica flour/epoxy cement and the whole vessel then lined with a cement to a thickness of about $\frac{1}{4}$in. Because the bottom 9in of the tank was very badly corroded, the cement was reinforced with layers of glass cloth to give extra support.

7. Part of the dedusting equipment on a boiler plant consists of a series of coned sections of cast steel flanged together. Because of the large size (about 3ft diameter) and hardness of the sections it is very difficult to make vacuum-tight joints and consequent air leaks reduce efficiency. To minimise these the outside of sixteen of the flanged sections after the joints have been made have been sealed by first trowelling a silica flour/epoxy cement around the circumference, followed by a wrapping of 2in wide glass cloth soaked in unfilled epoxy resin.

8. In early 1958, the heavy casting forming the casing of a river water pump had become severely eroded, especially where the 30in diameter stainless steel sealing rings seat in the body and cover. Fig. 3 shows a general view of the pump with its cover removed.

It would have been very costly and difficult to make repairs by orthodox methods ; a new casting might have been necessary. Accordingly, a resin repair was attempted and is still satisfactory after about $2\frac{1}{2}$ years' running time. The eroded parts were filled up, after grit blasting, with an aluminium powder/glass-fibre-filled epoxy resin cement and shaped approximately to the required profiles using the sealing rings covered with a separating agent as moulds. The repaired pump cover was machined

Fig. 5—River water pump ; corroded cast iron body with repaired areas

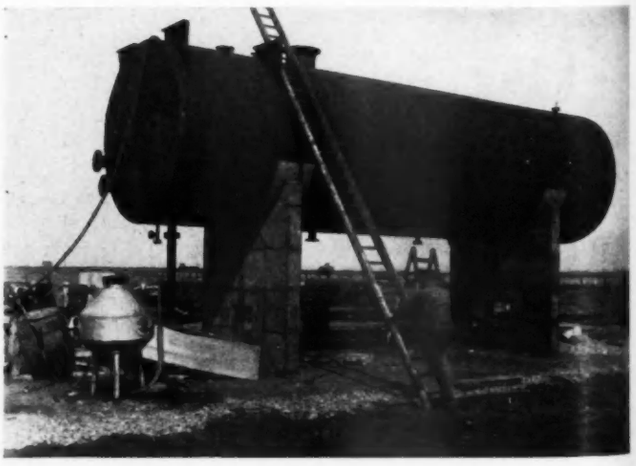

Fig. 6—Brine tank

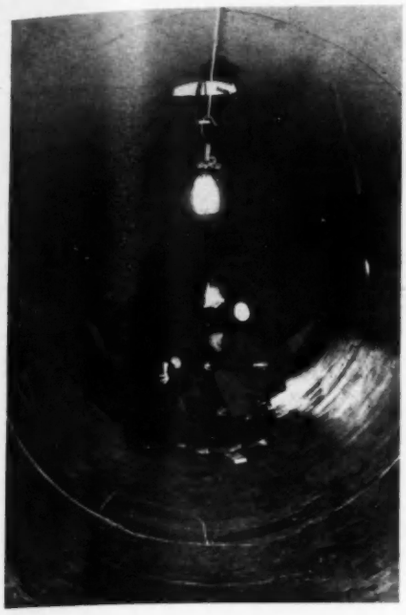

Fig. 7—Brine tank ; inspection of epoxy lining

accurately to shape while the body, which could not be moved, was finished *in situ* by hand-scraping ; substantial amounts of metal had to be replaced and about 25 lb of the resin cement was used, equivalent to about $\frac{1}{4}$ cubic foot. Fig. 4 shows the replaced "metal" seat for one of the sealing rings. The pump cover was removed after about eighteen months' running for a routine inspection and the resin repairs were found to be in perfect condition. The sealing rings could be replaced without any further repairs to their seats being necessary. Cement that had been applied to deep holes in the casing had withstood the erosion without signs of wear although adjacent cast iron areas had become deeply pitted (Fig. 5). The erosion resistance of the cement is so good that complete linings would be worth while.

Other pumps have since been repaired in the same way.

9. Some large mild steel oil storage tanks that have been in use for many years are developing leaks in their bases caused by corrosion from the underside. Holes through the bases can be made good by welding, but it is difficult to locate the holes and welding is administratively difficult because of fire and explosion hazards. The most positive way of repairing the tanks would be to weld in new bases, but this is difficult and expensive. Various alternatives were considered : the maintenance of a water level at the bottom (for liquids lighter and non-miscible with water), covering the base with clay, casting a slab of concrete in the base or covering it with a layer of resin cement. It was decided to try the last on a 50ft diameter, 1500 m³ tank. A silica-filled polyester cement was tried first over a small area, but it failed to set properly. Apparently there was some phenolic material left on the steel which inhibited setting even though the tank base had been grit-blasted. The epoxy cement, however, was applied and set satisfactorily. The whole base was covered with a layer of cement varying in thickness from $\frac{1}{16}$in to $\frac{3}{16}$in and the leaks stopped. The cost was much less than the cost of a new welded-on base. This tank has now been in service satisfactorily for about six months and two others of similar size have recently been repaired in the same way. Of course, the tanks are now limited to materials which do not attack the cement.

10. Fig. 6 shows a large mild steel tank required as a buffer vessel for the storage of brine. The tank in its previous service had been corroded on the inside near the bottom. To provide a protective coating that could be applied quickly, the affected areas were first grit-blasted and then coated with silica-filled epoxy cement to a thickness of $\frac{1}{10}$in to $\frac{1}{8}$in. Fig. 7 shows the coating being inspected before acceptance. Coatings of this kind, when fully set, are robust and can be walked upon without fear of damaging them.

11. Many other applications have been made. These include the taking of profiles of metal surfaces using special non-adhering polyester resins, the repair of vitreous enamelled plant, and phenol formaldehyde resin and ebonite lined plant, the provision of oil-excluding coverings for lagging and a large number of adhesives jobs. An important recent application has been the emergency repair of electrical insulators used in a mine winding installation.

The considerable practical experience that has been gained with epoxy and polyester resin repairs shows that they are not too difficult to carry out and there are now many which have proved to be reliable after prolonged use. The materials are versatile and can be used for a wide variety of plant applications. While substantial direct financial savings have already been made and plant shut-down times reduced, there is no doubt that, with wider publicity, many more profitable applications can be found. It is suggested that resin repairs should be accepted along with other repair methods, e.g. welding. Maintenance personnel can be trained quickly, in one or two days, to make the repairs.

For general use, the epoxy cements are preferred to the polyester in spite of their higher price, but for special jobs involving considerable amounts of resin the possible use of the polyesters should be considered.

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Stresses in a Ductile Material Subject to Biaxial Plastic Strain

By W. L. BRIDE, M.Sc.Tech., M.I.Mech.E.*

From experience gained in service and in laboratory investigations, thin-walled bellows may be stressed safely beyond the initial limit of proportionality of the ductile material used in their manufacture. This produces elasto-plastic conditions under load and residual strain on removal of the loads causing the stresses. Fig. 1 shows experimental stress investigations carried out by Munro and Miller, Ltd., on the firm's standard range of "Bellex" expansion joints, using electrical resistance gauges to measure axial and circumferential strains, in which stresses of this nature were encountered. It was then necessary to compute the stresses from these strains, each of which is partly elastic and partly plastic. Were the problem reversed the strain components, elastic and plastic, could be deduced from the known stresses, using one of the appropriate theories of plastic strain. In this article this procedure is adopted, first by applying the orthogonal shear stress theory to develop a graphical method of determining the strain components from known stresses. This makes possible the development of a semi-graphical method of solving the more practical problem of determining the stresses from the measured total strains. To illustrate the method two examples are worked out in detail to determine the stresses from known total strains. To check these results the strain components are calculated from the derived stresses, in each case their sum giving the original total strain.

IT is assumed that in simple tension or compression the stress-strain curve of the material is of the form shown in Fig. 2(*a*) so that there is proportionality up to the point *E*, but beyond this increasing stress produces an increasing rate of strain which is partly elastic and partly plastic.

It is further assumed that the total strains are known in two directions coinciding with the directions of the principal axes of strain.

The stresses producing these strains are of such magnitudes that the material is in an elasto-plastic state indicated by the existence of residual strain on removal of the loads on the structure. For example, such conditions are met with in expansion bellows subject to internal pressure or axial loading.

In an elastic biaxial stress system, in which principal stresses are σ_x and σ_y, the principal strains are

$$\varepsilon_{xe}=\frac{1}{E}(\sigma_x-\nu\sigma_y) \quad . \quad . \quad . \quad (1a)$$

$$\varepsilon_{ye}=\frac{1}{E}(\sigma_y-\nu\sigma_x) \quad . \quad . \quad . \quad (1b)$$

where ν is Poisson's ratio and E is Young's modulus for the material. In a ductile material of the nature defined above the limit of the elastic conditions occurs when

$$\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y=f_0^2 \quad . \quad . \quad . \quad (2)$$

where f_0 is the elastic limit of proportionality in simple tension. On co-ordinate axes of σ_x and σ_y of Equation (2) plots as an ellipse in which the major and minor axes are at 45 deg. to the σ_x σ_y axes. Transforming the equation to the axes of the ellipse gives

$$\frac{\sigma_x'^2}{a^2}+\frac{\sigma_y'^2}{b^2}=1 \quad . \quad . \quad . \quad (2a)$$

where the major semi-axis, $a=\sqrt{2}\,f_0$

$$. \quad . \quad . \quad . \quad (3a)$$

and the minor semi-axis, $b=\sqrt{\frac{2}{3}}\,f_0$

$$. \quad . \quad . \quad . \quad (3b)$$

Fig. 3 shows the plot of this ellipse and the graphical representation of principal stresses and principal strains for a point *P* on the ellipse corresponding to a biaxial stress system which is at the limit of elastic behaviour.

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Technical Contributors Section *(continued)*

Fig. 1

If the stresses are such as to introduce some plastic strain in the material, the elastic principal strains are, as before

$$\varepsilon_{xe}=\frac{1}{E}(\sigma_x-\nu\sigma_y) \quad . \ . \ . \quad (1a)$$

$$\varepsilon_{ye}=\frac{1}{E}(\sigma_y-\nu\sigma_x) \quad . \ . \ . \quad (1b)$$

and the plastic principal strains are

$$\varepsilon_{xp}=\frac{1}{E_s}\left(\sigma_x-\frac{\sigma_y}{2}\right) \quad . \ . \ . \quad (4a)$$

$$\varepsilon_{yp}=\frac{1}{E_s}\left(\sigma_y-\frac{\sigma_x}{2}\right) \quad . \ . \ . \quad (4b)$$

in which E_s is the secant modulus, for plastic strain only, in simple tension of magnitude f where

$$\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y=f^2 \quad . \ . \ . \quad (5)$$

Referring to Figs. 2(*a*) and 2(*b*), let the ratio $BC/AB=k$. Then $E_s=E/k$ and the plastic strains are

$$\varepsilon_{xp}=\frac{k}{E}\left(\sigma_x-\frac{\sigma_y}{2}\right) \quad . \ . \ . \quad (4c)$$

$$\varepsilon_{yp}=\frac{k}{E}\left(\sigma_y-\frac{\sigma_x}{2}\right) \quad . \ . \ . \quad (4d)$$

As shown in Fig. 4, these may be represented graphically in a manner similar to those for elastic strains.

If the stresses σ_x and σ_y were known and the simple stress-strain diagram for the material is determined, the elastic and plastic strains could be found graphically as shown in Fig. 5 for a stress point P. For each pair of values of stress co-ordinates of P (σ_x, σ_y), which lie on the ellipse

$$\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y=f^2 \quad . \ . \ . \quad (5)$$

there will be corresponding co-ordinates of a strain point P' which lies on the ellipse given by

$$X=\frac{1}{E}\left[\sigma_x+k\left(\sigma_x-\frac{\sigma_y}{2}\right)\right] \quad . \ . \quad (6a)$$

$$Y=\frac{1}{E}\left[\sigma_y+k\left(\sigma_y-\frac{\sigma_x}{2}\right)\right] \quad . \ . \quad (6b)$$

On the XY axes this is the equation

$$X^2+Y^2+\frac{(3k^2-4)}{(3k^2+6k+4)}\cdot XY = \frac{(3k^2+8k+4)^2}{4E^2(3k^2+6k+4)}\cdot f^2 \quad . \ . \quad (7)$$

which, when transformed to the X' Y' axes, becomes

$$\frac{X'^2}{a^2}+\frac{Y'^2}{b^2}=1 \quad . \ . \ . \quad (7a)$$

where the major semi-axis, $a=\frac{(k+2)}{\sqrt{2}E}\cdot f$ (8a)

and the minor semi-axis, $b=\frac{(3k+2)}{\sqrt{6}E}\cdot f$ (8b)

Hence for any stress point P of the equation

$$\frac{\sigma_x'^2}{(\sqrt{2}\cdot f)^2}+\frac{\sigma_y'^2}{\left(\sqrt{\frac{2}{3}}f\right)^2}=1 \quad . \ . \quad (9)$$

there is a corresponding strain point P' on the ellipse of the equation.

$$\frac{X'^2}{\left(\frac{k+2}{\sqrt{2}}\cdot\frac{f}{E}\right)^2}+\frac{Y'^2}{\left(\frac{3k+2}{\sqrt{6}}\cdot\frac{f}{E}\right)^2}=1 \quad . \ . \ . \quad (7a)$$

This is shown in Fig. 5 in which the horizontal and vertical components of PP' represent ϵ_{x_p} and ϵ_{y_p} respectively to the scale $1\text{in}=T/E$ units of strain and the

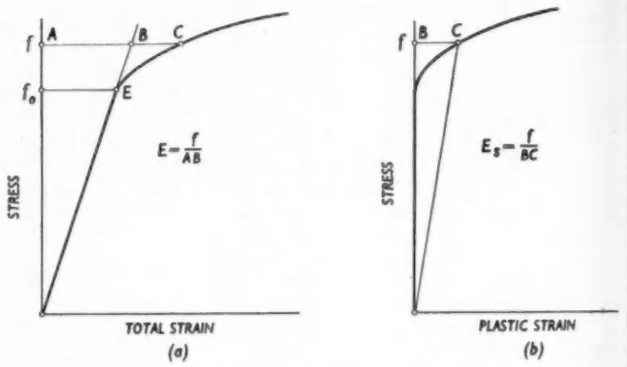

Fig. 2

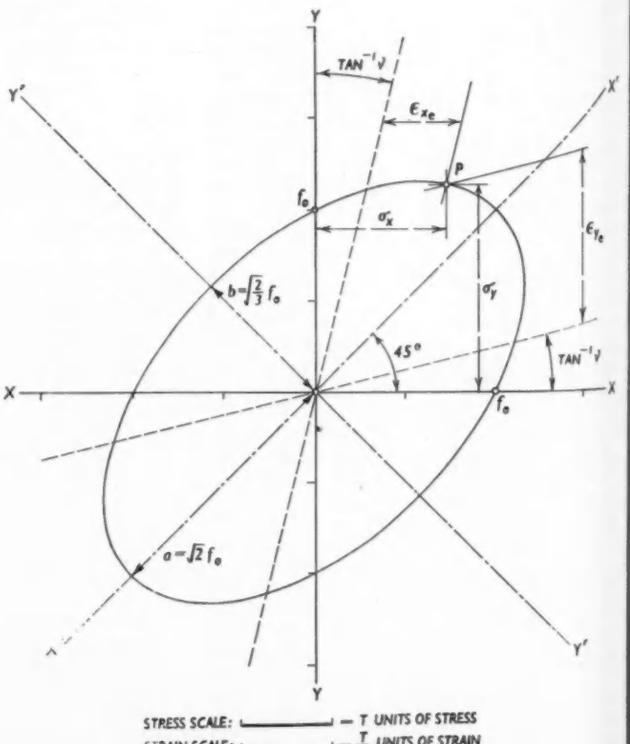

Fig. 3

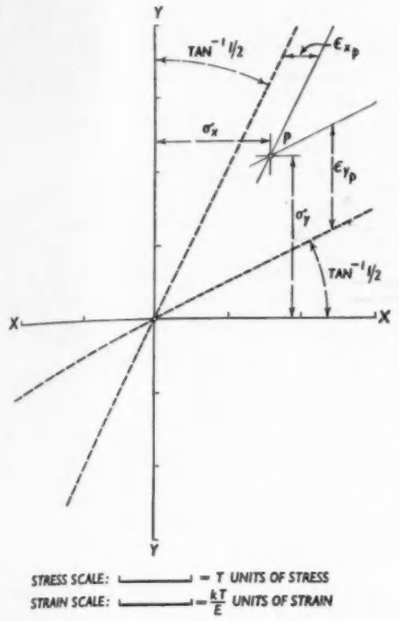

Fig. 4

horizontal and vertical components of SP represent the elastic strains to the same scale. The vector sum, PP', of the components of plastic strain, ϵ_{x_p} and ϵ_{y_p}, is normal to the tangent at P of the ellipse,

$$\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y=f^2 \quad . \quad . \quad . \quad (5)$$

Though the above method enables the elastic and plastic strains to be deduced from the known stresses, this is of little use in experimental stress analysis where only the total strains are measured and the stresses must be obtained from them.

On Fig. 6, P'' represents a strain point located by the measured total strains ϵ_{x_T} and ϵ_{y_T} where

$$\varepsilon_{x_T}=\varepsilon_{x_e}+\varepsilon_{x_p}=\frac{1}{E}\left[(\sigma_x-\nu\sigma_y)+k\left(\sigma_x-\frac{\sigma_y}{2}\right)\right] \quad . \quad . \quad . \quad . \quad (10a)$$

$$\varepsilon_{y_T}=\varepsilon_{y_e}+\varepsilon_{y_p}=\frac{1}{E}\left[(\sigma_y-\nu\sigma_x)+k\left(\sigma_y-\frac{\sigma_x}{2}\right)\right] \quad . \quad . \quad . \quad (10b)$$

The co-ordinates of ϵ_{x_T} and ϵ_{y_T} transformed to the X' Y' axes give the equation

$$\frac{x'^2}{a^2}+\frac{y'^2}{b^2}=1 \quad . \quad . \quad . \quad (11)$$

where the major semi-axis,

$$a=\frac{\sqrt{2}f}{(1-\nu^2)E}\left(1+\frac{k}{2}+\frac{k\nu}{2}-\nu^2\right) \quad . \quad . \quad (12a)$$

and the minor semi-axis,

$$b=\frac{\sqrt{2}f}{\sqrt{3}(1-\nu^2)E}\left(1+\frac{3k}{2}-\frac{3k\nu}{2}-\nu^2\right) \quad (12b)$$

For a given material k has a unique value for each particular value of f. This relationship is determined from the simple tension stress-strain curve. When k and f are known from the position of P'' and its relation to the ellipse (Equation (11)), σ_x and σ_y may be found from

$$\sigma_x=\frac{E\left[\left(\nu+\frac{k}{2}\right)\varepsilon_{y_T}+(1+k)\varepsilon_{x_T}\right]}{(1+k)^2-\left(\nu+\frac{k}{2}\right)^2} \quad . \quad (13a)$$

$$\sigma_y=\frac{E\left[\left(\nu+\frac{k}{2}\right)\varepsilon_{x_T}+(1+k)\varepsilon_{y_T}\right]}{(1+k)^2-\left(\nu+\frac{k}{2}\right)^2} \quad . \quad (13b)$$

The application of this is best explained by a worked example.

Fig. 7 shows a simple stress-strain curve for a material which, when subject to a biaxial stress system, showed total principal strains

$$\epsilon_{x_T}=20\cdot83\times10^{-4}$$
$$\epsilon_{y_T}=11\cdot83\times10^{-4}$$

Poisson's ratio for the material is $\frac{1}{4}$. From the stress-strain graph in simple tension $E=10{,}000$ tons per square inch.

From the stress-strain graph, values of AB and BC are measured and tabulated. From these a series of values of $k=BC/AB$ are evaluated. The graph relating k and f for the material is shown in Fig. 8. For each value of f, the major and minor semi-axes of the ellipses (Equation (11)) are calculated from Equations (12a) and (12b) respectively. These calculations are summarised in the Table above.

The ellipses corresponding to Equation (11) for each value of f and k are shown in Fig. 9. They were drawn with elliptic trammels, a convenient and quick method. Once prepared they may be used for any number of stress analyses for that material.

TABLE

f tons/sq. in	AB	AC	BC	$k=BC/AB$	*	†	$a\times10^4$	$b\times10^4$
15	1·5	1·5	0	0	15	15	21·213	12·247
15·5	1·55	1·58	0·03	0·01935	15·1935	15·3483	22·203	12·949
16	1·6	1·68	0·08	0·05	15·5	15·9	23·381	13·847
16·5	1·65	1·81	0·16	0·097	15·97	16·746	24·843	15·04
17	1·7	1·97	0·27	0·0159	16·59	17·862	26·59	16·528
17·5	1·75	2·175	0·425	0·243	17·43	19·374	28·758	18·455
18	1·8	2·45	0·65	0·361	18·61	21·498	31·582	21·063
18·5	1·85	2·83	0·98	0·53	20·3	24·54	35·407	24·711

* $1+\frac{k}{2}+\frac{k\nu}{2}-\nu^2$ † $1+\frac{3k}{2}-\frac{3k\nu}{2}-\nu^2$

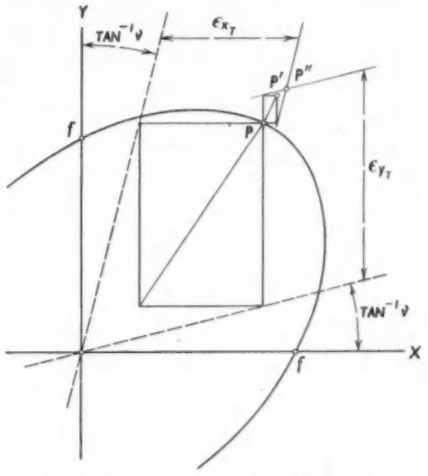

Fig. 6

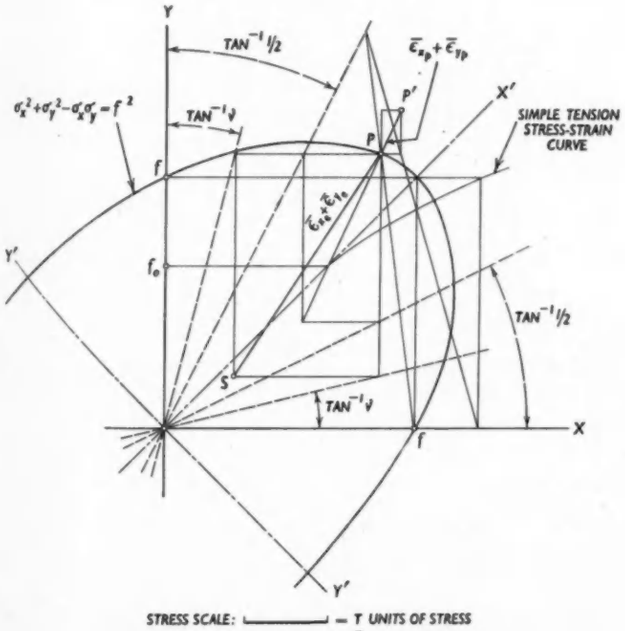

Fig. 5

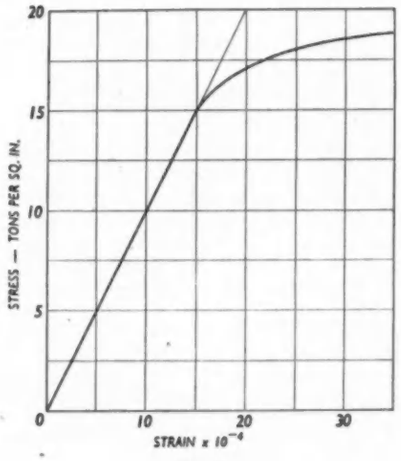

Fig. 7

The point P_1'', corresponding to the total strains $\epsilon_{x_T}=20\cdot83\times10^{-4}$ and $\epsilon_{y_T}=11\cdot83\times10^{-4}$, is located on this diagram, from which the correct value of f is, by interpolation, 18·05 tons per square inch. From Fig. 8, $k=0\cdot366$.

The stresses σ_x and σ_y are then calculated from Equations (13a) and (13b), respectively.

Technical Contributors Section (*continued*)

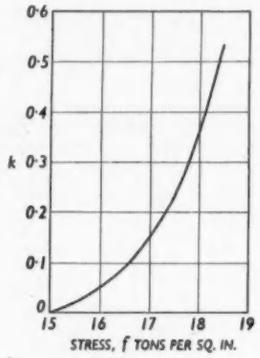

Fig. 8

$$\nu+\frac{k}{2}=0\cdot25+0\cdot183=0\cdot433$$

$$\left(\nu+\frac{k}{2}\right)^2=0\cdot433^2=0\cdot1875$$

$$1+k=1\cdot366$$

$$(1+k)^2=1\cdot366^2=1\cdot866$$

$$\sigma_x=\frac{E\left[\left(\nu+\frac{k}{2}\right)\varepsilon_{y_T}+(1+k)\,\varepsilon_{x_T}\right]}{(1+k)^2-\left(\nu+\frac{k}{2}\right)^2}$$

$$=\frac{10{,}000\,(0\cdot433\times11\cdot83+1\cdot366\times20\cdot83)10^{-4}}{1\cdot866-0\cdot1875}$$

$$=\frac{5\cdot12+28\cdot44}{1\cdot678}=\frac{33\cdot56}{1\cdot678}$$

$$=20 \text{ tons per square inch}$$

$$\sigma_y=\frac{E\left[\left(\nu+\frac{k}{2}\right)\varepsilon_{x_T}+(1+k)\varepsilon_{y_T}\right]}{(1+k)^2-\left(\nu+\frac{k}{2}\right)^2}$$

$$=\frac{10{,}000\,(0\cdot433\times20\cdot83+1\cdot366\times11\cdot83)10^{-4}}{1\cdot678}$$

$$=\frac{9\cdot03+16\cdot12}{1\cdot678}=\frac{25\cdot15}{1\cdot678}$$

$$=15 \text{ tons per square inch}$$

Each of the total strains may now be split into the two parts, elastic and plastic.

The elastic strains are

$$\varepsilon_{x_e}=\frac{1}{E}(\sigma_x-\nu\sigma_y)=\left(20-\frac{15}{4}\right)10^{-4}=16\cdot25\times10^{-4}$$

$$\varepsilon_{y_e}=\frac{1}{E}(\sigma_y-\nu\sigma_x)=\left(15-\frac{20}{4}\right)10^{-4}=10\cdot0\times10^{-4}$$

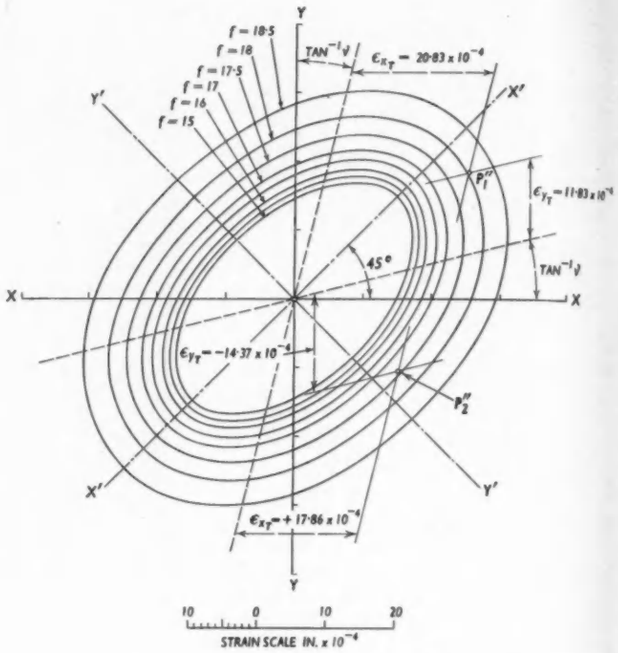

Fig. 9

The plastic strains are

$$\varepsilon_{x_p}=\frac{k}{E}\left(\sigma_x-\frac{\sigma_y}{2}\right)=0\cdot366\left(20-\frac{15}{2}\right)10^{-4}$$

$$=4\cdot58\times10^{-4}$$

$$\varepsilon_{y_p}=\frac{k}{E}\left(\sigma_y-\frac{\sigma_x}{2}\right)=0\cdot366\left(15-\frac{20}{2}\right)10^{-4}$$

$$=1\cdot83\times10^{-4}$$

Adding these

$$\varepsilon_{x_T}=(16\cdot25+4\cdot58)10^{-4}=20\cdot83\times10^{-4}$$

$$\varepsilon_{y_T}=(10\cdot0+1\cdot83)10^{-4}=11\cdot83\times10^{-4}$$

A further example is worked out for the same material in which $\epsilon_{x_T}=17\cdot86\times10^{-4}$ and $\epsilon_{y_T}=-14\cdot37\times10^{-4}$. These correspond to the strain point P_2'' on Fig. 9 from which $f=17\cdot48$ tons per square inch and, from Fig. 8, $k=0\cdot241$.

$$\left(\nu+\frac{k}{2}\right)=0\cdot25+0\cdot1205=0\cdot3705$$

$$\left(\nu+\frac{k}{2}\right)^2=0\cdot3705^2=0\cdot1373$$

$$1+k=1\cdot241$$

$$(1+k)^2=1\cdot241^2=1\cdot541$$

$$\sigma_x=\frac{10{,}000(0\cdot3705\times-14\cdot37+1\cdot241\times17\cdot86)10^{-4}}{1\cdot541-0\cdot1373}$$

$$=\frac{16\cdot83}{1\cdot404}=\underline{12 \text{ tons per square inch}}$$

$$\sigma_y=\frac{10{,}000\,(0\cdot3705\times17\cdot86-1\cdot241\times14\cdot37)10^{-4}}{1\cdot404}$$

$$=\frac{-11\cdot22}{1\cdot404}=\underline{-8 \text{ tons per square inch.}}$$

The elastic strains are

$$\varepsilon_{x_e}=\left(12+\frac{8}{4}\right)10^{-4}=14\times10^{-4}$$

$$\varepsilon_{y_e}=\left(-8-\frac{12}{4}\right)10^{-4}=-11\times10^{-4}$$

The plastic strains are

$$\varepsilon_{x_p}=0\cdot241\left(12+\frac{8}{2}\right)10^{-4}=3\cdot86\times10^{-4}$$

$$\varepsilon_{y_p}=0\cdot241\left(-8-\frac{12}{2}\right)10^{-4}=-3\cdot37\times10^{-4}$$

Adding these

$$\varepsilon_{x_T}=(14+3\cdot86)10^{-4}=17\cdot86\times10^{-4}$$

$$\varepsilon_{y_T}=-(11+3\cdot37)10^{-4}=-14\cdot37\times10^{-4}$$

ACKNOWLEDGMENT

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U.K. Atomic Energy Authority

(*Concluded from page* 91, *July* 21)

No. III—RESEARCH AT HARWELL

The seventh annual report of the United Kingdom Atomic Energy Authority published recently covers the year ended March* 31, 1961. *The following article, which is based on the report, supplemented by observations made during a recent visit to the Atomic Energy Research Establishment, Harwell, deals with some aspects of the current research programme. The topics touched upon include nuclear physics research and some of the relevant apparatus, radiation damage, methods of treatment of radioactive wastes, and heat transfer research.*

Nuclear Physics Research

RESEARCH in basic nuclear physics is one of the special responsibilities of the A.E.R.E., Harwell. For experimental studies of the internal structure of nuclei and of the mechanisms that determine nuclear reactions, considerable use is made of large electrostatic generators and particle accelerators. Prominent among the former machines is a tandem generator, the great merit of which is that it can produce very high beam energies whilst maintaining good energy resolution : the beam energy can be defined to one or two parts in ten thousand.

The tandem electrostatic generator, which was commissioned in 1959 is, in effect, two Van de Graaff machines in series. Its lower half is virtually a 6 MeV Van de Graaff generator. But instead of positive ions, such as protons, being injected at the positive high-voltage terminal, the voltage-dividing stack and accelerating tube are extended an equal height above this terminal, the top end being earthed, and negative ions (such as protons with two attached electrons) are fed in there. After being accelerated to the 6 MeV terminal, the ions are stripped of their electrons, by a thin foil, so that they can then be accelerated through a further 6 MeV in the lower half of the machine. In this way proton or deuteron beams are obtained with very well-defined energies continuously variable up to 12 MeV. (Fig. 1) Beams of heavier ions, such as oxygen, can also be produced. Fast neutrons of any desired energy up to 30 MeV are obtainable by allowing the proton or deuteron beams to bombard suitable targets.

Neutron Transmission Experiments.—Both nuclear physicists and reactor designers are interested in the interactions of neutrons with atomic nuclei. The first, because of the need for detailed information about nuclear structure ; the second, because the data to be derived are essential in computing critical sizes and shielding thicknesses.

For this sort of work the tandem electrostatic generator can be used as a mono-energetic neutron source by allowing the charged-particle beam, which has a well defined energy, to strike a neutron-producing target. The most suitable targets are deuterium or tritium gas, which has been adsorbed by a thin metallic layer. The nuclear interaction between the beam particles and the target nuclei produces neutrons of known energy. Using such targets and the deuteron and proton beams of up to 12 MeV energy, which are available from the tandem generator, mono-energetic neutrons of any desired energy in the range from a few hundred kilo-electron-volts up to 30 MeV can be produced. The ranges of 8–14 MeV and 23–30 MeV are of particular interest since they cannot be reached by electrostatic generators.

The total cross section for the interaction of neutrons with nuclei of a particular substance (that is a measure of the probability that a neutron will interact with one of the nuclei when it passes through a sample of the material) can be calculated from measurements of the attenuation of a neutron beam as it passes through such a sample. To make such a measurement a neutron detector (the " main " counter) is set up a short distance from the neutron source, which is the well-defined spot where the particle beam from the accelerator strikes the neutron producing target. A sample of the substance of interest is made up so that, when it is placed between the neutron source and the " main " counter, no neutron from the source can reach the counter without passing through the sample. Measurements of the counting rate in the " main " counter are then made with the sample in place and with the sample removed, and the attenuation of the neutron beam by the sample is computed as the ratio of these two counting rates. During the experiment the neutron production from the source is monitored by a second neutron counter (the " monitor " counter) which is placed in such a position that the scattering sample does not come between it and the neutron source.

To ensure that neutrons from the source do not reach the counters by scattering off the surrounding material, the source is kept well away from the walls of the experimental room, and the room itself is constructed with a light ceiling and a light floor which covers a pit 20ft deep.

In a typical experiment measurements are being made of the total neutron cross section of helium in the neutron energy range 22–30 MeV. The helium gas is contained at a pressure of 2000 lb per square inch in a long pressure vessel ; to make the " sample out " measurements an evacuated, but otherwise identical, pressure vessel is substituted for the one containing the helium. Measurements will also be done on a number of solid elements such as carbon, beryllium, lithium and calcium ; in these cases small blocks of the material can be used as the scattering samples.

The Broad Range Magnetic Spectrograph.—Each neutron and proton inside the nucleus can be regarded as moving in its own special orbit, and in a nucleus containing a hundred or so particle orbits the combined pattern of motion is extremely complicated. One way of studying part of this pattern is to provide the nucleus with an opportunity of acquiring additional energy and endeavouring to find out what new patterns of motion are created. Such an opportunity is provided in a nuclear reaction. The nucleus may acquire energy from one of the particles in an accelerated proton beam, causing some of its own particles to move in new orbits and thereby producing a new combined pattern of motion. The energy required to excite the new pattern is a precise quantity and is characteristic of the nucleus being studied.

For example, Harwell is studying the properties of the 1·18 MeV level in the Tin-120 nucleus. In this experiment a beam of 10 MeV protons impinges upon a tin target and the energy of the emerging protons is accurately measured. Most of the protons emerge with their energy unchanged but a few will have surrendered some of their energy to the tin nuclei. The protons which have lost energy reveal the energy levels of the tin nuclei. To separate a particular level

* " United Kingdom Atomic Energy Authority, Seventh Annual Report, 1960–61." H.M. Stationery Office. Price 5s.

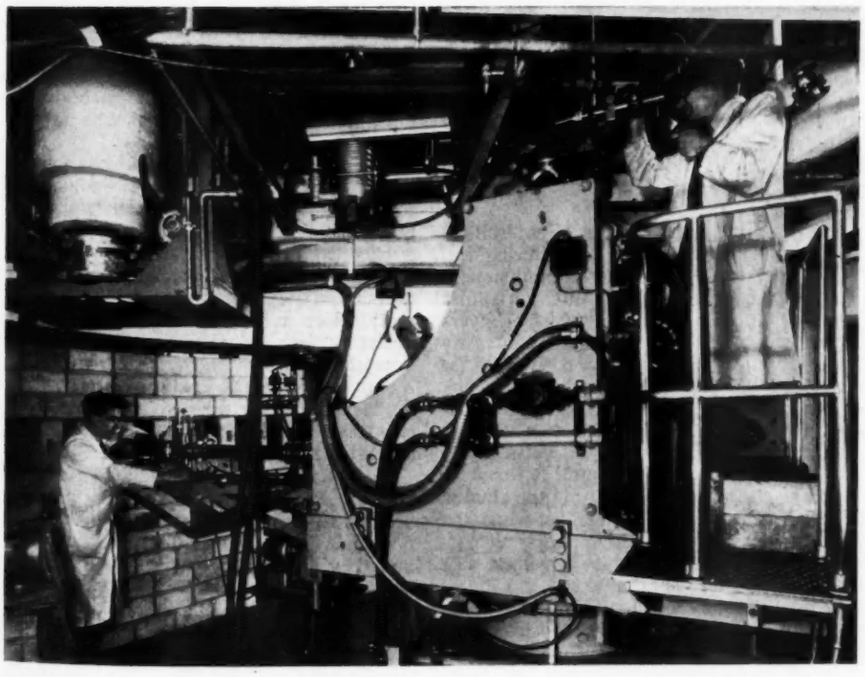


Fig. 1—Optical alignment of electromagnet at base of tandem electrostatic generator. The collimated beam emerges through control slits in the pipe on the left

Fig. 2—A beam of protons from the tandem generator enters the scattering chamber (centre) through the long evacuated pipe (right). Particles scattered by a target enter the spectrograph (left) and strike a photographic plate in the box above

from the others, the experimenter needs, in addition to extreme beam energy precision, a very accurate method of measuring the energy of the outgoing protons. The broad range magnetic spectrograph meets this requirement very well; it is the most accurate energy measuring instrument available.

Essentially, the magnetic spectrograph (Fig. 2) is a powerful electromagnet with an evacuated box clamped between the pole pieces. In the Harwell experiment, protons from the tin target enter the instrument through an evacuated pipe at the bottom of the box, travel in circular paths in the magnetic field and strike a long (27in) photographic plate placed at the top of the box. The magnetic field sorts the protons according to energy so that protons having different energies strike different parts of the plate. After development, the plate is examined under a microscope. The point of impact of each proton can be clearly seen as a thin black track against a background of light, and the number of tracks is found to vary along the plate. The position on the plate of each group of tracks provides an accurate energy determination, and the number of tracks yields the number of protons with that energy. The spectrograph magnet is mounted on a heavy turntable so that it can measure the variation in the number of protons emitted in different directions. Such variations with angle can give additional information about the energy levels.

5 MeV Van de Graaff Machine.—Two other machines may be mentioned: one is a 5 MeV Van de Graaff generator and the other is a 3 MeV pulsed Van de Graaff generator. The former machine, which is in service for about ninety hours (average) per week, is used for about half this time on measurements of neutron cross sections needed for reactor design. This cross-section programme will be considerably extended when the new 3 MeV comes into operation, but the 5 MeV machine will continue to be used for this work, making use of its higher energy levels.

About a quarter of the running time of the 5 MeV machine is given to pure research in low-energy nuclear physics. Most of the remaining quarter is devoted to experiments on radiation damage to determine the changes in physical and chemical properties of materials exposed to neutron fluxes, both for reactor design considerations and for health-physics purposes. An example is the variation of semiconductor properties of a silicon rectifier under neutron bombardment. Since these properties are very sensitive to slight changes of structure, useful results can be obtained quickly with far lower fluxes than occur in a reactor.

"IBIS": Fast Neutron Time of Flight Experiment.—The 3 MeV Van de Graaff generator known as "IBIS" (Intense Bunched Ion Source) is the first machine of its kind to be specially designed for the measurement of neutron velocities and, by deduction, neutron energies. Very short bursts are produced to give high precision in timing and a very high intensity is achieved (at least twenty times greater than any existing machine) which permits the use of long flight paths.

The machine, built by the High Voltage Engineering Corporation at Burlington, Massachusetts, is just being commissioned. It consists basically of a 3 MeV horizontal Van de Graaff accelerator which delivers bursts of protons or deuterons of intensity 1mA, duration ten nanosecond (one nanosecond=1/1000,000,000 second) and spacing one microsecond. The particles are then bent through 90 deg. by a large-aperture magnet after being swept sideways by a varying electric field. The latter is timed so that the leading particles of the bunch follow a long path in the magnet while the later particles follow shorter paths, all particles arriving at the target together. In practice, the pulse is compressed to a duration of one nanosecond, its intensity rising to 10mA. Using a variety of nuclear reactions this machine can produce monoenergetic neutrons at energies of from 30 keV up to 6 MeV and from 14 MeV to 20 MeV.

A very important component is the electronic timing system which has been developed at A.E.R.E. This makes use of a time expanding circuit which multiplies time intervals by 250. The expanded time intervals are measured against an oscillator clock and the times recorded on magnetic tape to an accuracy of ½ nanosecond. In a typical experiment an energy resolution of better than 1 per cent is expected.

The most important class of measurement that will be made is a study of neutron inelastic scattering. Neutrons of a well defined energy are produced by "IBIS" and scattered from a small sample. Some may lose large amounts of energy which will reappear as γ-radiation. The energy and angular distributions of the scattered neutrons and γ-rays will be measured; this information is of great importance to the design of fast reactors and reactor shields. In addition, information will be obtained on the fundamental processes of inelastic neutron interaction with nuclei which are not at present well understood. Using the same methods the machine will be a formidable tool for nuclear spectroscopy of the heavier elements. A study will be made of reaction mechanisms and nuclear spectroscopy amongst light nuclei using the reactions (d, n) and (He^3, n). This programme continues work at present in progress on the 5 MeV Van de Graaff.

Semiconductor Materials.—The use of semiconductors for the detection of nuclear particles is an interesting development which originated in America and is now being pursued along independent lines at Harwell. The energy resolution of these detectors can be as good as 15keV, which is enough to discriminate, at, say, 5MeV, between groups of particles differing by only 0·3 per cent in energy. Previously, sensitivities of this order were possible only with expensive magnets weighing about 4 tons and costing about £5000, with auxiliary equipment. On the other hand the new detectors weigh about 1 gramme each, they can easily be prepared in a small laboratory, the cost of materials being about £2 per detector, and the auxiliary equipment is simple. As there is good proportionality of output with particle energy the detectors are easily calibrated. Fast-coincidence work is possible because the pulse is very rapid, rising to a peak in 10^{-9} seconds. Another advantage is that the detectors are comparatively insensitive to unwanted backgrounds of gamma rays or neutrons.

The principle of operation is as follows. In a semiconductor diode (P-N junction) there is a region at the junction which is practically an insulator. When a voltage is applied (in a reverse-bias direction) electrons are repelled from this volume, which becomes deeper and may extend for a millimetre from the junction itself. When a charged nuclear particle enters, it ionises the silicon, producing electrons which are very rapidly collected by the strong electric field across this insulating layer. The arrival of the electrons at the electrodes provides a pulse which can be amplified and recorded.

A simple method of producing the required "surface barrier" detector has been developed at Harwell. An N-type silicon disc is chemically etched to give a clean surface and then allowed to oxidise, when a P-type layer forms spontaneously on the surface. This is an insulator, and electrical contact is made by evaporating a thin gold film on the area which is to be sensitive. Contacts are made to the gold and the back of the silicon by conducting cement. The P-N junction exists between the thin surface layer and the bulk silicon.

The process can be adapted to produce some useful variations. For example, although the detectors are normally fairly insensitive to neutrons, a neutron flux detector can be prepared by mounting a thin plastic foil in front of a counter. Neutrons collide with hydrogen nuclei (protons) in the foil and these recoil into the silicon counter, where they are detected in the usual way. This simple device fills a gap in the range of present neutron flux instruments in the range of energies 2–6 MeV. Another variant is a multiple counter of many separate strips of gold evaporated on to one crystal.

Radiation Damage

Study of radiation damage is important in the development of fuel elements, solid moderator materials and structural components of reactor cores. There are two main effects. First, the atoms composing the materials may be displaced from their normal positions by collision with high energy particles. For example, fast neutrons cause damage in structural or moderator materials and the fission fragments, generated in nuclear fission, cause damage in nuclear fuels. The displaced atoms and vacant atomic positions created by irradiation are mobile, and clusters of both types of defect can develop ; these defects cause changes in mechanical properties and, in some instances, changes in dimensions. Secondly, neutron irradiation causes nuclear reactions in irradiated materials. The most important consequences of these reactions arise from the accumulation of fission product gases in irradiated fuel or of helium in irradiated beryllium ; in both cases the inert gas formed causes the material to swell at elevated temperatures or to become brittle at lower temperatures.

Graphite.—Work on graphite irradiation consists of two parts—basic studies, the object of which is to determine the nature of the disorder produced in the crystal lattice and its effect on physical properties, and technological work, which is carried out to obtain information on the behaviour of graphite under the conditions which are encountered in practical reactors. The basic work requires a relatively small investment in man-power and equipment, but the technological work requires a large engineering effort in order to obtain the correct conditions for irradiation. The irradiation tests are carried out with accurate temperature control and in a sufficiently intense neutron flux to make it possible to obtain, in the course of two or three years' work, an irradiation dose equivalent to that encountered in the whole life of a power reactor. Sufficiently high irradiation fluxes for this purpose have been obtained by the use of special fuel elements in the " Dido " and " Pluto " reactors, and irradiation rigs have been designed which give the required temperature control. The results of experiments using this equipment have been used in the design of the first commercial power reactors and have enabled a satisfactory choice of operating temperatures to be made. The work is being continued to obtain similar information for more advanced systems and to study the effects of irradiation on improved types of graphite which may be using these systems.

The most interesting recent development in the basic studies of irradiation damage is the direct observation of damage using the electron microscope. For this purpose thin films of graphite, about one millionth of an inch thick, are examined by transmission of electrons. The existence and aggregation of defects in the crystal lattice can be seen clearly. In addition to this direct observation of damage, indirect methods of study are being used. In these methods the effect of irradiation on the electrical and thermal properties of graphite are being studied. Other basic studies are being undertaken to determine the effect of using different types of bombardment particles and, in particular, the effects of bombarding with neutrons of different energies.

Metals.—Growth under irradiation, previously demonstrated in alpha uranium, has now been induced in other anisotropic metals by irradiation with fission fragments. These new results have assisted theoretical understanding of growth processes. The growth of six metals has been investigated at liquid nitrogen temperature (—196 deg. Cent.) and at 75 deg. Cent. Magnesium and beryllium showed no growth at either temperature, while growth was observed at both temperatures in zirconium and titanium. The remaining two metals, cadmium and zinc, exhibited growth at the lower temperature only. When growth was observed it was always found to take place in the direction of lowest thermal expansion. This indicated that the local anisotropic expansion in the region of disorder created by the stopping of a fission fragment (the so-called fission spike) may play an important part in the growth process. This view is supported by the observed behaviour of magnesium, which is isotropic in its thermal expansion and showed no growth under fission fragment bombardment. Beryllium is thought to have shown no growth because the fission spike formed in the metal under irradiation with fission fragments is small. Other experiments, in which uranium was irradiated with 3 MeV protons at 80 deg. Cent., also indicate that no growth occurs if the displacement spikes are small. The same techniques are now being used to study the detailed geometry of growth in uranium.

Uranium.—The " swelling " of irradiated uranium is due mainly to the gaseous fission products, krypton and xenon. For typical irradiations and temperatures, the volume of these gases at atmospheric pressure might be several times that of the original uranium. It has been shown by electron microscopy that minimum swelling is associated with a very fine dispersion of small bubbles of gas, typically about 0·1 micron in diameter, at a fairly regular spacing of about 0·5 micron. In these circumstances the gas pressure, of the order 1 ton per square inch, is fully restrained by surface tension forces. If the bubbles are more coarsely distributed they may grow, presumably because they can collect gas atoms and vacancies from a larger volume. A point is ultimately reached when surface tension becomes relatively unimportant and the bubbles expand against the creep strength of the metal. Even when the bubble distribution is fine, however, metallographic examination of irradiated material has shown that significant contributions to swelling can result from cracks and ragged holes at grain boundaries which are on a much larger scale than the fine bubbles. Several mechanisms for the initiation of such cracks and holes are being investigated ; these include the sweeping-up of bubbles by grain boundary movements and intercrystalline stresses arising from thermal cycling.

Beryllium.—The effect of neutron irradiation on the physical and mechanical properties of beryllium is being studied using electron microscope " thin film " techniques. At Harwell the beryllium is electrolytically thinned ; at Windscale cleavage flakes for examination have been produced by fracturing. By these methods bubbles smaller than 10^{-6}cm have been seen in beryllium irradiated to very high neutron doses. The presence and size of these bubbles depend both on dose and temperature ; they are believed to be the main cause of the changes in mechanical properties. For example, the bubbles are thought to be responsible for the decrease in the ductility of beryllium which takes place at high neutron doses. On present evidence, however, neither bubble formation nor loss of ductility appear likely to be substantial in the dose and temperature ranges of current interest in reactors.

Research on Ceramic Fuels

In recent years the Authority have become increasingly interested in the use of ceramic fuels in power reactor systems. Most research has so far been done on uranium oxide systems, although uranium carbide, mixed uranium and plutonium oxides, and dispersions of mixed oxides in steel (cermets) are also of interest. The first step in the examination of the properties of ceramics and cermets is to establish the conditions required to obtain homogeneous bodies of low porosity. Successful techniques of preparation have been devised by paying close attention to the mechanism of sintering and to the behaviour of the materials concerned over a wide range of experimental conditions. Thus, a novel technique has been developed at Harwell for the preparation of uranium carbide, with low open-pore space, by the " reaction sintering " of uranium and carbon powders ; this is based on the retention of liquid uranium for a closely-controlled and limited time. This method is of considerable potential interest since it would replace expensive arc-melting and casting methods. Detailed studies of the effect of the sintering atmosphere and temperature on composition, and on inter-diffusion processes, have permitted the successful preparation of homogeneous and stoichiometric uranium/plutonium dioxide solid solutions of low porosity from the mixed oxide powders ; this process is much more convenient than co-precipitation from solutions.

Uranium oxide has a low thermal conductivity and, when irradiated in a reactor, steep temperature gradients are set up and cracking takes place. Steeper temperature gradients will cause growth of the oxide grains and, at the extreme, centre melting will occur. At lower temperatures the release of fission product gases from the oxide is controlled by the rate of diffusion through the oxide ; if the irradiation conditions are such that grain growth, together with migration of pores, takes place then a much higher fraction of the fission product gases is released. Novel experimental techniques have been devised, in which oxide samples can be subject to large and controlled temperature gradients, to study these structural changes in unirradiated material.

An understanding of the properties of single crystals is essential if the behaviour of polycrystalline ceramics is to be understood. A recent achievement has been the production of single crystals of pure uranium dioxide by electrolytic deposition from a solution of uranyl chloride in fused alkali metal chlorides. The physical properties of these crystals, for example their plasticity and structure, are now being studied. Neutron diffraction techniques have been devised to study the positions of the uranium and oxygen atoms in single crystals over a range of oxygen contents and temperatures.

Polycrystalline ceramic materials are brittle and so have a poor resistance to thermal shock ; the mechanisms which give rise to this undesirable property have been studied. The first experiments have been made on

magnesium oxide, a typical brittle ceramic which can readily be prepared in the single crystal form ; the experiments will later be extended to uranium compounds. It has been shown that the brittleness of magnesia is due to the presence of surface cracks, less than one thousandth of an inch in length, which grow during deformation and lead to fracture. A typical crystal, if quenched from about 200 deg. Cent. into cold water, will disintegrate. But, if the microcracks are removed by chemical polishing, a crystal can be quenched from 1000 deg. Cent. without even cracking. The next step is to study bi-crystals since the grain boundaries in the polycrystal are sources of weakness. It should eventually be possible to decide whether or not it is practicable to make a more ductile ceramic.

Studies of plutonium and uranium oxide systems are also being made at Harwell from the chemical point of view. Both uranium and plutonium dioxide can exist with oxygen contents which differ from the content indicated by the chemical formula (two atoms of oxygen per metal atom) and the precise oxygen content affects many of their physical properties (e.g. ease of sintering, thermal conductivity, ability to retain fission products). Recent work has established the oxygen content of uranium dioxide as a function of oxygen pressure and temperature. A special technique (the measurement of electromotive force at high temperatures) has also been developed to characterise and investigate an oxygen composition range which covers the probable oxygen composition of the uranium dioxide in A.G.R. fuel elements. High temperature X-ray diffraction measurements on plutonium oxide systems have identified two intermediate oxides of plutonium between PuO_2 and Pu_2O_3. Chemical studies are also being carried out on the behaviour of uranium dioxide under irradiation. These include investigations of crystal lattice deformations using X-ray diffraction, of the chemical changes which take place when uranium oxide is irradiated in a carbon dioxide atmosphere, and of the factors which govern the retention of fission product atoms within the uranium oxide lattice.

Research on Fluidised Beds

Fluidisation is a technique of increasing importance in the chemical industry and it is used, for example, in several stages of the process used by the Authority in manufacturing uranium from ore concentrates. The technique involves passing a fluid, either gas or liquid, upwards through a bed of particles. Under these conditions, there is a threshold fluid flow above which the bed lifts and is supported by the fluid. At higher fluid flows the bed itself behaves as a fluid. These so-called fluidised beds provide very good contact between the solid particles and the fluid, have a fairly uniform temperature distribution and have extremely good heat transfer conditions. Although there have been many successful applications of the fluidised bed technique, the underlying theory is ill-defined and successful design is essentially empirical. Investigations at Harwell, which are aimed at establishing the basic theory on a firm basis, have principally been directed towards studying the gas and solid flow patterns in fluidised beds. A variety of experimental techniques, including the use of radioactive tracers, has been employed. One typical investigation was designed to relate the formation and behaviour of bubbles in the fluidised beds to the movements of the gas and solids. These experiments have shown that the roof of a bubble is robust and that a pocket of gas does not rise through a rain of solid particles, as had been thought in the past. It has also been shown that streams of gas adjacent to bubbles enter through the sides and bottom of the bubbles and mix inside them. This work suggests that bubbles, which have often been thought a disadvantage and a sign of gas channelling, may help to promote gas mixing. Although the stability of bubbles once formed has been demonstrated, a good deal more work remains to be done before the conditions for the formation of bubbles can be defined. The problem of gas distribution in a fluidised bed is one of the most important factors in the design of a successful plant.

Fluidised beds can be used to carry out single-stage chemical operations. Many chemical reactions, however, have to be carried out under counter-current conditions which can at present only be achieved with fluidised beds by operating several in cascade. A number of advantages could be gained if a single fluidised bed could be operated to provide the required conditions. It is now known that tapered beds, that is, beds in which the cross-sectional area of the bed increases with height, can provide these conditions. Experimental work is therefore being undertaken to determine the effects of bed height, angle of taper, and other factors in relation to the other bed variables (e.g. solid characteristics, gas flow). Among the more important conclusions reached is that there is a minimum bed height below which the advantages of counter-current flow may not be obtained.

Treatment of Radioactive Wastes

Research at Harwell on radioactive wastes has been directed towards developing methods for separating radioactive constituents from waste solutions and for converting them into a form which can be stored cheaply and safely until the natural process of radioactive decay reduces their activity to harmless levels. The most highly active wastes, such as those deriving from fuel element treatment plants, are evaporated to small volume for storage in stainless steel tanks. Laboratory work over the last few years has shown that it may be possible to store these materials more conveniently by incorporating them into insoluble glass-like solids. The method used was to convert nitric acid solutions of fission products into glass by heating the solution, as a slurry, with silica and borax. More recent experimental work has demonstrated that this method will produce satisfactory glass-like materials on the scale which would be required in an operating plant. A pilot plant study (1000 curies per batch) is now being carried out to obtain data on which the design of a full-scale plant could be based.

This project is known as "FINGAL" (Fixation in Glass of Active Liquors). In this process a stream of the fission product waste solution in nitric acid is mixed with a stream of slurried borax and silica and the slurry pumped through a narrow pipe into the top of a steel cylinder 5ft long and 6in in diameter. The cylinder is situated in a segmented furnace which enables the input of heat to be regulated along the length of the cylinder. The liquid entering the hot vessel is rapidly evaporated, denitrated and the residual oxides fused to glass. This glass is continuously formed in the vessel and when the level has risen to about 40in the operation is stopped and the glass is allowed to cool. The steam and nitric acid vapours that are produced leave the vessel and are conducted through a second cylindrical vessel identical with the first, excepting that this vessel contains a filter and absorber for dust and volatile ruthenium, to a condenser and scrubber system. When glass-making is complete in the first vessel it is cooled and then removed from the furnace to storage. The second vessel is now moved into the furnace and a third clean vessel, with filter installed, takes its place.

The mode of storage of the glass vessels after their removal from the furnace is not decided. The fission product decay will generate about 1kW of heat in each vessel during the first few years of storage and during this period the vessels must be cooled. Both air and water cooling have been proposed and an assessment of the relative merits of both systems is in progress. It does not seem that the storage of vessels produced at the rate of a thousand a year presents any difficulty, especially when the storage form is a chemically inert insoluble glass.

Ion-exchange Plant.—The evaporation method of reducing the bulk of material to be stored is so expensive that it is only used for very highly active wastes ; chemical precipitation methods, or methods involving the use of ion-exchange, are much cheaper for medium and low-level wastes. Ion-exchange methods have been studied for some years at Harwell ; their use avoids the production of chemical sludges and gives a final concentrate of small volume for storage or disposal.

Recent work, in conjunction with a commercial firm, has shown that it is possible, by special regeneration techniques, to reduce the waste regenerant considerably. This has been done by two stage regeneration, re-use of part of the regenerant and rinse liquors, and by having small columns in series rather than a single large one. It was established that the most practicable and efficient system was a two stage unit, each stage consisting of treatment through cation and then anion exchangers. To make maximum use of the ion-exchange capacities of the resins, treatment was continued until activity back-through occurred at the second stage. At this point only the resins in the first stage were regenerated and the stages reversed for the next treatment ; the effluent passing through partially exhausted resins before final treatment through the freshly regenerated material. In this way full use was made of the capacity of the unregenerated resins and the loading on the freshly regenerated ones reduced since they became the second stage. This scheme proved to be efficient and overcame the old problem of high waste arisings previously experienced with ion-exchange systems.

The ion-exchange plant at Harwell was designed from data obtained in the laboratory development work and is capable of treating radioactive effluent at a rate of 500 to 1000 g.p.h. The plant consists of four columns which contain, alternately, cation and anion-exchange resins. In the first column cations, both inactive and radioactive ions, are exchanged for hydrogen ions to give a large reduction in the radioactive content of the effluent. On passing through the second column, inactive and radioactive anions are exchanged for hydroxyl ions which combine with the hydrogen ions, liberated from the first column, to form water. Thus the first stage of the plant effects a considerable reduction in the radioactivity and replaces it by water. The second stage works in the same way and gives the final decontamination of the effluent.

Since the resins remove all the ions from solution, demineralised water of low conductivity emerges after the second stage.

This conductivity remains at a low value during treatment, rising very rapidly when the resins in the second stage begin to lose their efficiency. It has been shown that this rise in conductivity occurs before activity break-through and can, therefore, be used to indicate the end of treatment.

A conductivity meter is incorporated in the plant after the second stage to give a continuous reading of the purity of the treated water. When this meter shows a rapid rise in conductivity the treatment is stopped and the resins in the first stage are regenerated, using acid for the cation and alkali for the anion. The less active part of the regenerant liquors is retained for re-use while that containing most of the activity is removed for storage. After a short rinse, with treated water, treatment is continued, the second stage of the previous treatment now becoming the first stage.

This plant will be used to treat medium level active effluent and investigate further the use of ion-exchange materials for the treatment of radioactive effluent. It will also be used to compare the cost of treatment with, for example, the two-stage chemical precipitation ion exchange system, which at the pilot plant stage, at Harwell, has a capacity of 1000 gallons per hour and consists of sludge blanket precipitators, followed by ion exchange columns.

Electro-deionisation Through a Packed Bed.—The ion-exchange method cannot be used on a fully continuous basis since the ion-exchange material has to be chemically regenerated from time to time. Laboratory studies of the related technique of electro-deionisation (in which ion-exchange materials are incorporated into an electrolytic cell) have shown that higher concentration factors may be achieved using this method. Electro-deionisation also offers the possibility of continuous operation, since the ion-exchange material can be continuously regenerated, without adding chemicals, by passing an electric current at right-angles to the solution flow. A small pilot scale cell has been successfully operated at solution flows of 50 gallons per hour. This has shown that electro-deionisation is particularly suitable for treating solutions which have low salt contents. The work is being continued using cells capable of dealing with solution flows of up to 500 gallons per hour.

The principle involved is that a solution passes through a bed of mixed exchanger material, which is held between two membranes. One of these is permeable to cations only, and other to anions only, and a current passes at right angles to the liquid flow in such a way that both cations and anions are removed from the mixed bed through the membranes. Under these conditions the mixed bed is converted partly to the H^+ and OH^- form. The system can, therefore, be considered as a chromatographic column with continuous electrolytic regeneration. When a solution of constant composition runs through a column of this sort, a steady state is set up, and a solution of constant composition arises as product.

This kind of equipment is particularly useful for the deionisation of dilute solutions ($\Delta N/100$), which to de-ionise in normal cells without packing would require high voltages on account of the polarisation occurring in the unstirred layer close to the membranes. The packed cell, therefore, offers considerable possibilities for the final decontamination of radioactive waste solutions. In the case of the packed cell, this polarisation does not arise, as conduction proceeds through the ion exchanger beads and not through the aqueous solution.

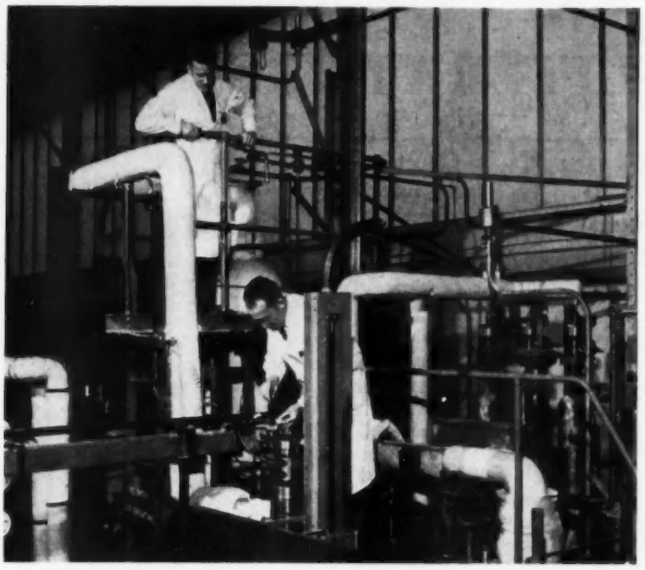


Fig. 3—Maintenance on high pressure steam-water heat transfer loop

Heat Transfer Research

Improved methods of removing heat are being studied at Harwell. In one system wet steam is used as the coolant. If the water in the steam is present as a film or spray very high heat removal efficiencies can be obtained, but the efficiency falls if the steam becomes too dry. Heat transfer experiments at relatively low pressures have been in progress for some time to try to correlate the steam conditions (such as the degree of dryness) with the heat removal characteristics and to determine the limiting conditions. These experiments have shown promise and are being extended to higher pressures. Parallel experiments on the behaviour and stability of films of water have been carried out using air and water under conditions of flow which simulate the steam-water system.

In one experiment, with an air/water rig, the characteristics of film flow are being studied electronically in two ways. The first involves the use of slightly conducting water : by placing electrical resistance probes in the wall of the tube the local thickness of the film can be measured and displayed in magnified form on a cathode-ray oscilloscope. The second is an optical method in which beams of light passing through capillary tubes inserted through the wall of the tube, are partly absorbed by dye in the water before falling on miniature photo-electric devices. By making simultaneous measurements at two or more points, wave velocities can be estimated. Two entirely different wave types are shown to be present, travelling at very different velocities : slow ripples and fast Helmholz waves.

A similar, but very tall, air/water rig is used to make measurements of the degree of entrainment of water in the form of spray, and its distribution across the tube, using refined multiple-probe techniques. The spray may be an important factor in heat transfer and "burn-out." The shape of the spray distribution, which depends upon the manner of injecting the water, varies according to position along the tube and has not completely stabilised even after 30ft.

Another experiment makes use of a low-pressure heat transfer rig in which separately metered flows of steam and water are mixed and fed to the base of a test section containing an electrically heated rod. Instead of a simple annulus, the rod is surrounded by copper blocks (which can be heated), shaped to represent adjacent heated rod elements, thus simulating a rod-bundle. The rod-spacing can be varied over a wide range. A transparent plastic model of the test section will be used for film flow measurements. In a typical "burn-out" test, actual melting of the element is prevented by eletronic equipment which detects the rapid asymmetrical temperature rise and switches off power in about seventy milliseconds.

A large rig has been built (Fig. 3) for making similar heat transfer studies at high pressures (up to 1500 lb per square inch), using at present a simple annulus. In this case the steam cannot be taken from the main but must be generated in an oil-fired furnace (1·25 million B.Th.U. per hour), and recirculated after condensation. The heater element, 29in long and 0·375in diameter, can be supplied with up to 100kW of power. Incipient burn-out (at a loading of about 250 per square centimetres) is detected and prevented as in the low pressure rig.

From all the experimental equipment, data are produced at such a rate that their assimilation and analysis would be the chief limitation on the work, but for the Harwell "Mercury" computer. The experimental readings are, therefore, recorded in such a way that they can be fed directly to the computor, hence allowing the data to be available in usable form a very short time after each experiment.

Liquid Level Controller

Control and indication of the level of any conducting liquid with a specific resistance not exceeding 50,000 ohms per centimetre cube is provided by the "Resistron" liquid level controller of Thomas Industrial Automation, Ltd., Station Buildings, Altrincham, Cheshire. In operation, a small a.c. potential is applied to the liquid via electrodes, and the voltage developed across an internal potentiometer network controls a thermionic valve which in turn operates a relay. Models are available for high-level or low-level working, or for both modes with a selector switch. Failure of the valve or a component de-energises the relay to the "safe" condition. In all models the relay is a dust-protected unit having one normally closed and one normally open contact rated at 5A, 250V a.c. non-inductive load. Red and green signal lamps are fitted in the cover of the controller, which in a sheet steel or heavy industrial cast iron case measures 4¾in wide by 6⅞in high by 4½in deep. A special electrode can be supplied to enable the device to be used as a gauge for sorting small metallic parts.

[Reply Card No. 1107]

LITERATURE

Book Reviews

Radio and Electronic Components. Vol. 5. Wires and R.F. Cables. By G. W. A. DUMMER and W. T. BLACKBAND. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 47s. 6d.

THE authors of this book are to be congratulated on having produced what should prove to be a valuable reference volume for the electronics and telecommunications industry, in particular for those engaged in the wire and cable making industry. It forms the fifth of a series which cover the common components employed in the field of telecommunications and electronics: the first four volumes deal with fixed and variable resistors and fixed and variable capacitors. The first two chapters are confined to a brief historical introduction to the subject of components and include comprehensive references to specifications and publications appertaining to wires and cables in general. The majority of these are either British Standards or Defence Specifications. There are two main parts to the book. The first part concerns Wires and Sleeving, and the second part Radio Frequency Cables.

Part I consists essentially of an invaluable collection of tables and appropriate references to British and other Standards supplemented by brief but useful technical matter. A useful feature is that the collection of data is unique in that it represents one of the first attempts in this country to consolidate such information in book form. A brief account is given of the manufacturing techniques employed for the various categories of insulated wires common to the electronic industry. The various physical, electrical and mechanical measurements and tests described are those common to most of the specifications. After a rather short survey of future trends and developments this part is concluded with an excellent bibliography under the subject heading of Insulated Wires.

Part II is concerned with Radio Frequency Cables. It must be pointed out that the range and types of cables described are, in general, those that are considered as components of electronic equipment, that is cables required for the internal wiring of apparatus, or for use as apparatus interconnecting leads. There is, however, one greatly expanding field where these flexible or semi-flexible cables are used which has not been mentioned. The radio and television relay companies are erecting many miles of cable networks for relay purposes. The cables employed are similar to those described in this book.

Because of the many distinct technical advantages of the coaxial or asymmetrical type of cable over the balanced or twin conductor type, the bulk of the data and information given is confined to the former. Emphasis is given to the question of universal standardisation of cable sizes and dimensions, and interesting information is given on the work of the International Electrotechnical Committee in this direction and the economic results of this rationalisation. The importance of this is further emphasised when it is realised that each type and size of cable employed requires corresponding and technically suitable end terminations in the form of plugs and sockets.

Very detailed lists are included of practically every type of Radio Frequency Cable manufactured throughout the world. This data is valuable to industry when the provision of suitable alternative types is desired. Three chapters are allocated to the theoretical aspects of the transmission of radio frequency energy over cables and the design and testing of them. The technical information contained in these chapters has been collected from a number of sources and represents a collection of data of practical application supplemented by the authors' wide experience. In the chapter on testing methods the inclusion of transient or pulse techniques would have been useful. The tests described are those most generally appropriate to the various specifications.

In the preparation of this book the authors have drawn almost exclusively on their very considerable experience mainly associated with the requirements and specifications of the Services. This, however, should not be considered a limitation of the book but, on the contrary, an advantage. As they have very wisely pointed out, the gruelling demands on equipment and components for the Services use are obviously so severe that specifications must take these factors into consideration. It follows therefore that whilst accepting the established Services designs, relaxation of the relevant specifications can reasonably be permitted for industrial purposes.

Continuous Casting of Steel. By M. C. BOICHENKO. Translated from the Russian by L. Herdan and R. Sewell. Edited by G. Fenton. Butterworth and Co. (Publishers), Ltd., 4 and 5, Bell Yard, London, W.C.2. Price 50s.

CONTINUOUS casting, which has been much in the news of late, and is likely to be more so in the future, is really much older in conception than is generally realised. It dates back, in fact, to 1868, when Bessemer proposed pouring liquid metal directly between rotating rolls. But there were many difficult metallurgical and engineering problems to be solved before the process, attractive though it was from a production point of view, became commercially practicable. Non-ferrous metals, of lower melting points than steel, were more tractable, and it was these metals which were first cast successfully by semi-continuous and continuous processes. Casting of steel came later, after much experimental work in various countries, including the United Kingdom, Germany, the U.S.A. and Russia. Continuous casting offers many advantages, not the least of which is increased output and it was this feature in particular which attracted the Russians, who have developed the process on a very big scale. It is now well past the experimental stage and commercial plants are in operation, under construction, or planned, in many parts of the world.

Several different types of continuous casting plants exist, but all are basically similar. Molten steel is poured into a water-cooled mould, where it skin-solidifies, and means are provided for withdrawing the resulting billet or slab continuously at the same rate as the pouring. Provision is also made for cutting the continuous length of solidified metal into pieces of a suitable size for further processing. With this fundamentally simple process quite a lot of heavy capital plant can be eliminated. Furthermore, if ever the dream of fully-continuous production of steel from furnace to finished product is to be realised, continuous casting in one form or another will be an essential feature of the process.

Like every other process, however, continuous casting is not without its problems, and its successful operation depends on careful metallurgical control, good engineering and a full understanding of fundamental principles. This book covers both the theoretical and practical aspects of the subject in a competent manner and does not, as is sometimes the case with technical books, assume that if the rules are followed, everything will be right with the product. On the contrary, it devotes an appropriate amount of space to things which could go wrong, and to means for avoiding trouble. In translation the author has been well served by his translators; the English text is good and the arrangement straightforward. A minor criticism is that some of the illustrations—particularly of individual sections of plant—are small and of poor quality.

Flexural Vibrations of Rotating Shafts. By F. M. DIMENTBERG. Butterworth and Co. (Publishers), Ltd., 4 and 5, Bell Yard, London, W.C.2. Price 60s.

THIS is a very interesting book which has been translated from the Russian by the Production Engineering Research Association and published in association with D.S.I.R. The author is associated with the Leningrad Steel Works and the "Elektrosila" Works, and many of the experimental results quoted in the book have been obtained at these works. On reading the book it is clear that he has carried out an exhaustive study of international papers on the subject of shaft vibrations and whirling. This is particularly evidenced from the extensive biography at the end and the frequent reference in the text to the works of well-known authors.

Starting with the simplest shaft rotor system, the analysis is developed in easy stages to cover the more complex symmetric and asymmetric systems, including such things as coupled rotors with heavy flexible bearings, multi-rotor systems including contra-rotating shafts, gyroscopic effects and distributed unbalance. At each stage of the analysis some of the lesser known whirling phenomena, such as the hysteretic effect due to internal friction and the stability of a system during acceleration through the critical whirling speeds, are analysed.

Having established an analysis covering the majority of systems one would encounter in the heavy turbine industry, with particular regard to the conventional calculations of critical whirling speeds and, what is not so common, the natural vibrations dependent on rotational speed, attention is drawn to what, in the author's opinion, are some of the more important problems associated with systems which run at speeds in excess of one or more of the critical speeds, i.e. the stability of the system at post-critical speeds. Here the hysteretic effect is important and as in previous analysis is included whenever

damping of the more conventional form is assumed. In his introduction, the author has tended to dismiss the normal calculations of critical speeds as being of little interest when one considers modern systems rotating at speeds greatly in excess of the critical and for this reason has devoted a large proportion of his book to the problems of stability in the trans-critical and post-critical speed ranges.

The author's emphasis on such things as gravity whirl and effects of internal damping may, however, be somewhat misleading to the designer. These effects are, in general, of importance only in certain cases such as heavy flexible systems with asymmetry of shaft stiffness and long span between bearings, and systems where the internal friction is increased by the use of shrink fits. An awareness of these "secondary" critical speeds is therefore important in the design stage, but in most cases they can be assumed to be the exception rather than the rule. However, this by no means detracts from the value of the book, although it is perhaps of greater value to the vibration specialist than the design engineer. In this respect it is perhaps surprising that no mention is made of the oil film effect in plain bearing systems, as this is a similar problem to that of internal friction but one which seems to occur more often in the kind of machinery that the author is concerned with. Also, if one considers bearing flexibility in the whirling calculation, the oil film effect on stiffness alone could be of a similar order and in a book of this calibre one would expect more than normal consideration of this effect. The effect of damping in the bearing is considered but only in a qualitative manner; no experimental work to assess the quantitative effect of oil film damping has been mentioned.

From the design viewpoint the book is of value as it brings to the notice of the designer some of the more unusual phenomena encountered in the whirling system, particularly when running at post-critical speeds. From the research viewpoint it provides a very useful theoretical approach for the research worker as a basis for experimental evaluation of some of the unpredictable parameters leading to various forms of instability at speeds other than the major conventional critical speeds. To anyone interested in the more complex aspects of shaft whirling here is a valuable addition to the library, unusual in its approach and diverse in content.

Surface Structures in Building. By FRED. ANGERER. Alec Tiranti, Ltd., 72, Charlotte Street, London, W.1. Price 18s.

HERE we have an illustrated description of the forms and variants of the shell roof. The author considers "it deals with the borderline between architecture and engineering. There is a danger that much is too superficial for the engineer and too detailed for the architect." Nevertheless many engineers will find general interest in the subject matter, which deals with composite "folded plate" structures as well as doubly and singly curved shells, showing sketches of actual structures or of designs of each type. The original edition was published in German, and the English version was translated by Mr. W. Redlich.

Pumping Data. Megator Pumps and Compressors, Ltd., 43, Berkeley Square, London, W.1. Price 10s.

CURVES and data sheets evolved by the Megator organisation for everyday use in the design of pumping installations are presented in this booklet, which is intended as a practical guide and a work of reference. The subject matter consists of the following headings: properties of liquids; quantities, heads and pressures; flow of liquid in pipes; pump installation and accessories; and conversion of units. There are also twenty-two charts relating to these various headings.

Rockets. By PAUL ADORIAN, F.C.G.I., M.I.E.E., M.Brit.I.R.E. Paul Adorian, 21, Denmark Street, London, W.C.2. Price 8s., post paid.

THE text of this booklet was originally a lecture to the Engineering Society of the City and Guilds (Engineering) College; it was delivered first on January 23, 1929, followed by a demonstration at model scale, and repeated on February 12, 1930. It has been reprinted and offered for sale in order to raise money for the Sir Henry Tizard Memorial Fund.

The paper is divided into two parts, the first considering the motion of a rocket in the absence of external forces such as gravity, and the second the development of actual examples. The two parts create conflicting expressions upon a reader in 1961; the mathematics of bodies of variable mass has now become so refined that the theoretical analysis seems laborious (when flights in real space are considered, it is in terms of extravagant straight-line paths with no coasting). The account of the engineering approaches is, however, at least in respect of German work, breathtaking; in January, 1928 Max Valier is writing in terms of an air turbo-rocket! A proposal for a rocket-propelled aeroplane shows that, then as later, Lippisch designs were incredibly futuristic; it resembles nothing so much as an Armstrong Whitworth A.W.52.

The booklet includes photographs of contemporary experiments on the Continent, including one spectacular failure close before a group of temerarious observers, and of the author's own rocket car which ran along a wire in the courtyard of the college.

From Theory to Practice in Soil Mechanics. Selections from the Writings of Karl Terzaghi. Prepared by L. Bjerrum, A. Casagrande, R. B. Peck and A. W. Skempton. John Wiley and Sons, Ltd., Gordon House, Greencoat Place, London, S.W.1. Price 96s.

The name Terzaghi is known to nearly every civil engineer in the world. This is a strange fact, for civil engineering is a broad subject and Professor Terzaghi impinged mainly on one facet, but his impression had such revolutionary effects that his name, and the name of soil mechanics became inextricably linked together.

That soil mechanics is now accepted as a basic dicipline of civil engineering, and takes its place with theory of structures and hydraulics, can be traced back to the fundamental approach of Terzaghi and is generally marked by the publication in 1925 of his *Erdbaumechanik*. Until then the approach had been empirical and "ad hoc," but gradually the meaning of his work came to be understood by civil engineers who realised its relevance to their needs. In this country the failure of the Chingford reservoir in 1938, when Terzaghi was called upon to advise, had extraordinarily far reaching effects. A delightful description of how he was brought to London is given in the biographical note by A. Casagrande, which is included in the book.

A year later he was again in London delivering the James Forrest lecture at the Institution of Civil Engineers. This lecture had a tremendous impact on the profession with its forthright directness, and as soon as the war was over every University in the country began to teach the principles that he had outlined and a new "subject" came into being.

This is all recent history and the biography is, on that account, very fascinating. When Terzaghi last addressed engineers in this country, at the 1957 International Conference on Soil Mechanics and Foundation Engineering, his personality, as always, cut through the proceedings, and his Presidential address, which is reproduced in this volume, gives an insight into the way this great man's mind has worked. Everyone who was there knew what he meant by the importance of "thinking with both the head and the hips," for it is this ability which differentiates the engineer from the technician and the engineer from the pure scientist.

The book is a collection of papers, reports and lectures by Terzaghi which date from 1913, on "Landforms and subsurface drainage in the Gacka Region of Yugoslavia," to one of his most recent papers, "Consultants, Clients and Contractors" published in 1958 in the Journal of the Boston Society of Civil Engineers. Even those with a good soil mechanics library will find in this book a number of worth-while papers which they had not previously met. This applies to his contributions to the first International Conference in 1936, which are not readily available outside a few large libraries. The additional material included in the book, by Professor Casagrande and Dr. Bjerrum about the man himself, makes delightful reading and, with Professor Skempton's assessment of the significance of Terzaghi's concept of effective stress, greatly add to its value.

Soon Terzaghi will be 80: he is a constant inspiration to those who know him, and by reading this work many more will come to understand how he achieved his reputation as one of the greatest civil engineers of our age.

Book of Reference

British Miniature Electronic Components and Assemblies Data Annual, 1961–62. Edited by G. W. A. Dummer and J. Mackenzie Robinson. Pergamon Press, Ltd., Headington Hill Hall, Oxford. Price 80s.—This is the first volume of an annual series intended to provide designers and users of electronic equipment with detailed information on components in the miniature class, which is taken to cover items up to approximately 1in cube. Components over these dimensions are included when they are the smallest in their particular category. Resistors up to and including ½W, and capacitors up to approximately 1in maximum body length are listed. Only components assembled or manufactured in the United Kingdom are covered. The book is arranged under alphabetical headings of components, including an "Assemblies" section for composite items such as miniature printed wiring, potted circuits, logic elements, and transistorised plug-in amplifier, counter and similar stages. This section will cover microminiature circuits as these become available.

Books Received

Full Scale Fatigue Testing of Aircraft Structures. Division IX: Symposia Volume 5. Edited by F. J. Plantema and J. Schijve. Pergamon Press, Ltd., Headington Hill Hall, Oxford. Price 100s.

Scientific Research in British Universities, 1960-61. Department of Scientific and Industrial Research, Charles House, 5-11, Regent Street, London, S.W.1. Obtainable from H.M. Stationery Office. Price 32s. 6d.

Drive and Control of High-Speed Lifts

A modern lift system for a large building can be compared to a railway with several two-way tracks, and trains following each other so closely that an intending traveller at any station has only a few seconds to wait for a journey in either direction. This article describes the various forms of "timetable," and the evolution of equipment for adapting the service to varying demands and accelerating the traffic.

CONSIDERABLE thought is being given at the present time to the application of electronic devices in the control systems of high-speed lifts operating to predetermined programmes. The first attributes of electronics which come to mind in studying this question are not always those of the greatest advantage in practice. For example, space saved by replacing electromechanical relays with semiconductor logic devices is often less important that it sounds, since the dimensions which have to be observed in planning a group installation usually result in ample room being available for the machines and their control boards.

Before considering how one manufacturer is using electronics in lift control, it is interesting to recall the evolution of the variable-voltage system used to-day for high-speed lifts (those operating at 500ft per minute and over). A problem met quite early with lift drives in large buildings having d.c. mains was the heavy instantaneous load imposed on the system and its effect on other services, such as lighting. This led to the use of motor-generator sets to supply the lift motors, taking advantage of the inertia of the machines for absorbing the peaks. An early system was to have several sets with their generators in series, and to connect the lift motor in turn across one, two, or more machines during acceleration.

The spread of alternating current distribution led to the development of various forms of a.c. motor drives for lifts. When more than one speed is necessary, the two-speed pole-changing motor has been as popular as any, for speeds up to 200ft per minute, being more silent than a slipring machine. For higher speeds, requiring fine control of acceleration, the Ward-Leonard set with a variable-voltage output supplanted the multi-generator scheme described above and is now universal for lifts in the speed category covered by this article (Fig. 1). The first application of the Ward-Leonard system to lifts in this country was in 1924 at Harrods in London, for which the firm of Waygood-Otis was responsible.

The needs of multi-storey buildings with large populations have seen the widespread installation of groups of lifts working to programmes which vary during the day, such adjustments being planned to make the best use of the capital expenditure involved. Some of the principles applied in planning lift installations of this kind, and the technical requirements to be met, have been explained to us by the Otis Elevator Company, Ltd. It is considered that the aim should be a maximum waiting time for a lift, at any landing, of thirty seconds. Waiting time is a function of the round trip time divided by the number of cars in service. Calculation of round trip time is based on the number of passengers and the number of floors. Where there are more than twenty floors and 2000 people in a building it becomes practicable to have separate groups of local and express lifts.

The Otis "Autotronic" system of group lift control provides for operation according to either four or six programmes planned to meet the varying demands on lift service during the day. The six-programme system is applicable to large buildings with four or more lifts. For smaller buildings the four-programme system is recommended. Both are well tried and proved with electromechanical control equipment. Electronics are being introduced in so far as it can be shown that their application saves money and maintenance time, and improves operation. These points are not considered only in terms of the present. The time occupied by the erection of new buildings obliges the designer of lift equipment to take a long-term view so that an installation shall not be obsolescent by the time it goes into service. This involves continuous study and research, the effects of which may not be apparent at any given moment.

Since electronic circuits are used in the "Autotronic" system in connection with programme scheduling, it is convenient here to consider the modes of operation of the four-programme system, which is the one more generally required in this country at the moment. They are as follows.

Up-Down Programme.—This applies during most of the day in the smaller building. Cars are dispatched automatically at frequent intervals, but :

(1) A car delayed *en route* can be passed

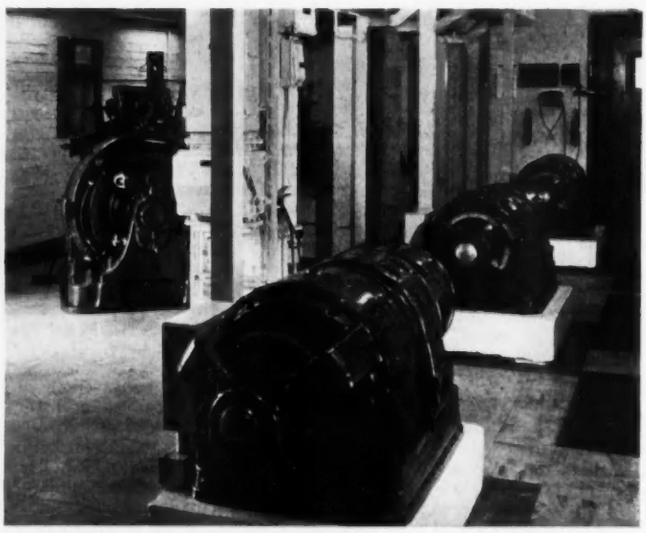


Fig. 1 (Above)—Motor-generator sets and drives for a typical high-speed lift installation

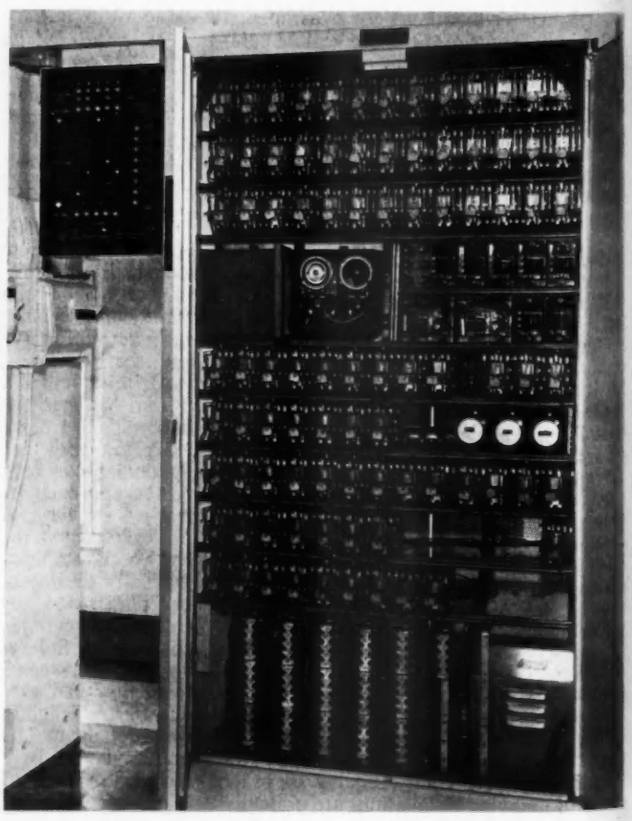


Fig. 2 (Right)—Dispatcher and controller cubicle with monitor panel showing car position, dispatching sequence, calls and programme in force

Fig. 3—Touch-button panel in lift car

by another car without disrupting dispatching signals.

(2) If "down" calls exist behind a down-travelling car, an up car that is late may be reversed at its highest call in order to answer them.

(3) A car is dispatched ahead of time from the lower terminal if the preceding car has completed its round trip and up calls exist behind it.

(4) A car which has become fully loaded (detected by floor weighing contacts) is run express and by-passes landing calls until its load is reduced.

Up-Peak Programme.—Here the object is to distribute passengers from the ground to the upper floors as quickly as possible.

(1) Cars are time-dispatched from the lower terminal only and reverse automatically when empty.

(2) A car that fills quickly is not held back but leaves as soon as it is full.

(3) "This Car Up" signs are illuminated automatically to show passengers which car to enter.

Down-Peak Programme.—This programme meets the situation of the home-going rush, taking account of the needs of passengers at intermediate floors so that they are not kept waiting unduly long because down cars are filled before reaching them.

(1) Cars are time-dispatched from the upper terminal, but start back from the lower terminal as soon as passengers are discharged.

(2) Up cars running late are reversed as soon as they have answered their highest call, in order to answer down calls behind preceding cars.

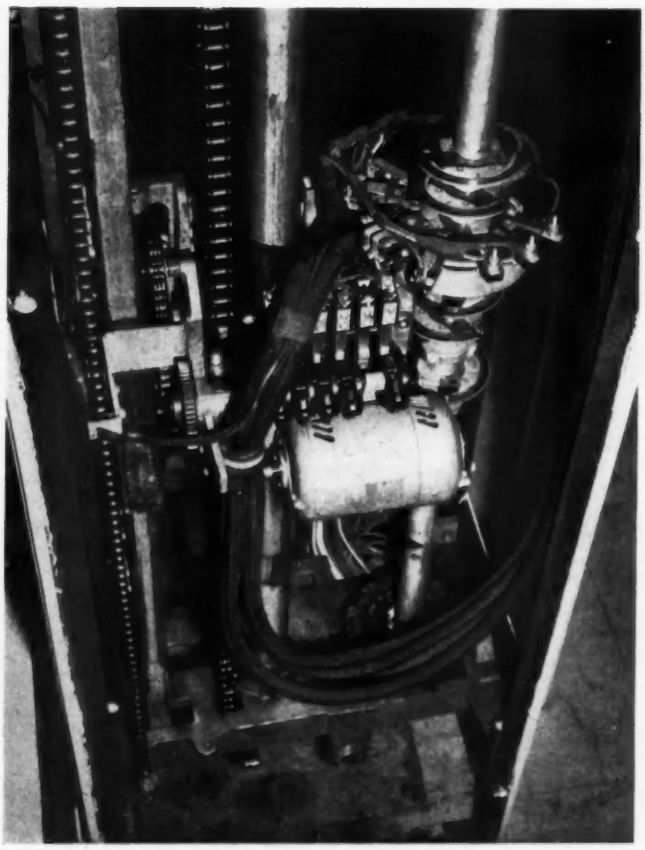
(3) Full cars run express.

(4) A zone return system operates if waiting times at lower floors reach a predetermined limit. The building is divided into a high zone and a low zone and all cars reverse at the highest call in their respective zones. To help low zone cars relieve floor congestion, unfilled high zone cars answer low zone calls until filled. When the severity of the down traffic condition lessens, regular down dispatching of cars is resumed.

Intermittent Programme.—This is for periods of night, week-end and holiday traffic. In smaller buildings one car remains in service and parks at the main floor. If traffic demand increases, additional cars are brought into service automatically for as long as necessary. Alternatively, two cars may remain in service (supplemented by others according to demand as before). All cars are arranged to park at the ground floor. Fig. 2 shows a typical despatcher and controller cubicle, for a system of the kind described.

Electronic circuits are used in the "Autotronic" system as part of the means of selecting and operating the above programmes. A twin triode and its associated circuits perform the functions of detecting demand and adjusting dispatch intervals accordingly. The principle of working is continuous comparison of a condenser timebase signal, representing the basic timetable, with signals from the selectors representing the movements of the cars. The Otis selector, installed in the machine room and driven by a toothed tape attached to the corresponding car, consists essentially of a crosshead travelling between vertical guides in synchronism with the car itself and operating "floor bars" to which are attached contacts associated with the control circuits.

An example of economy in equipment obtained by electronics is seen in the Otis electronic touch-button for cars and landings (Fig. 3). This is a gas-filled cold-cathode triode with thyratron characteristics. The touch-button is a plastic square, engraved with a floor number, connected through a hairspring with a plate on the tube envelope. An a.c. potential of 150V is applied to the cathode of the tube, while an a.c. component in the anode voltage causes the latter to vary in such a way as to be always 135V positive to cathode. This anode/cathode potential is insufficient to strike the tube:



Figs. 4 and 5—(Left) Interior of electronic cubicle with supply equipment and associated relays for touch-buttons. (Right) Selector mechanism, showing motor-operated drum switch on travelling crosshead for control of acceleration and deceleration according to distance to be run. The levelling speed controller is on the right

on the positive peak of each cycle the anode is 285V positive to earth. If, therefore, the plate on the envelope is earthed by a person touching the square with his finger, a discharge takes place between anode and plate, and this initiates an anode/cathode discharge. The latter is maintained as in an ordinary thyratron after the earth has been removed, and the tube continues conducting until the arrival of the car at the selected floor trips a switch in the cathode circuit. The system saves a relay and reduces wiring compared with a normal push button, while the tube serves as its own pilot light to show that the call has been registered. An electronic cubicle with supply equipment and associated relays for touch-buttons is seen in Fig. 4.

Tubes of the same kind are used in the Otis electronic detector which stops and reverses car and landing doors when a passenger is within a few inches of either door. In this case firing takes place between cathode and grid of the tube, and the capacitance effect is established between the passenger and antenna plates on the door edges. Reversals of the doors do not continue indefinitely, but are over-ridden after a preset time by a condenser-controlled timing relay. This causes a buzzer to sound and the doors to resume closing at low speed so that a passenger still between them is "nudged" out of the way.

The proximity detector described above has the advantage over photocells for the same purpose that reversals are fewer, since they do not occur until the doors are within a very short distance of a passenger. Therefore, although a passenger may enter the car after the doors have begun to close, he may well be clear of them before the critical distance is reached, so that the doors continue their movement without interruption. Passenger transfer time accounts for about one-third of lift operating time, and methods of avoiding delay are of great importance.

The Otis high-speed electric door operator contributes by its mode of working to the speedy loading and unloading of cars. It is driven by a ½ h.p. d.c. motor which runs with controlled acceleration and deceleration to open car and landing doors together. When lifts are attendant-operated, opening to a clearance of 3ft 6in can be accomplished in 1·1 seconds. Closing occupies the same time. Without an attendant it is desirable to slow the operation, and this is done on the closing motion, which is extended to 2·2 seconds. The supply to the motor is taken through a saturable reactor and rectified. Speed is regulated by an appropriately-controlled voltage applied to the reactor control winding. Throughout its operation the door motor is adjusted to develop only the torque necessary to obtain the desired door speed. Horizontal thrust is below 30 lb and reversal is arranged to take place within the detection zone. A hydraulic cushioning mechanism built into the gear unit brings the doors smoothly to rest, the motor driving torque being reduced at this stage.

Landing doors are operated by a vane attached to the car doors. To save time, opening of a car door actually begins during levelling at a landing. As the car approaches floor level the door vane engages rollers on the landing door, which is unlocked by the pressure on one of these rollers. Subsequent movement of the landing door breaks an interlock circuit, which is not restored until both doors are again fully closed. While this circuit is broken the car cannot be moved.

The importance of door operation is emphasised by the fact that attention to this and associated matters has enabled the operation of a high-speed lift serving sixteen floors to be improved by between 16 and 17 per cent over the past ten years.

The whole subject of doors, landings and access to lifts in general is one in which collaboration between architects and lift engineers at an early stage can do much to ensure that maximum benefit is derived from an installation. The question is complicated by the behaviour of the lift passengers, which follows a recognisable if illogical pattern. Passengers only travelling for one or two floors, for example, seem invariably to stand at the back of the car. Centre-opening doors encourage passengers to move forward as soon as a crack appears, but they tend to wait until a single-slide or two-speed door is fully open before alighting.

In order to minimise running time it is essential to maintain constant acceleration and deceleration rates at the maximum compatible with passengers' comfort, regardless of length of journey. This presents a major problem of design, for in a high-speed installation the stopping distances required for passenger comfort may be in excess of one floor, and in very high-speed machines may be as much as two to three floors. This means that when a one-floor run is required, the stopping devices would need to be operated before the lift car moved, and so acceleration would be slower than if a long run were to be made. To overcome this problem a motor-driven drum switch on the selector operates before the car starts to make the necessary corrections, according to the length of journey demanded, for constant acceleration and deceleration to be maintained. Fig. 5 shows part of a selector with the pilot motor and switch contacts.

Undoubtedly electronic devices will be used in lift systems on a growing scale. The maintenance service of a lift manufacturer affords unique opportunity for continuous study of how a system behaves after it has begun operation, and wherever electronics appear to offer a solution satisfactory on the three grounds already mentioned, their application is studied. Attractive as the elimination of moving contacts may seem, however, the advantage of being able to check the working of a system by listening to the beat of electro-mechanical relays is not to be lightly discarded.

Type-5 Diesel-Electric Locomotives

Twenty-two diesel-electric locomotives similar to the prototype "Deltic" of 1955 are going into service between King's Cross, Leeds and Scotland and will allow savings of between 40 min. and 60 min. to be effected this winter in the timings of six expresses between London and the North.

WHEN the prototype "Deltic" 3300 h.p. diesel-electric locomotive appeared in 1955, main-line diesel motive power on British Railways was confined to two 1600 h.p. units operating in the London Midland Region, and three of 1750 or 2000 h.p. in the Southern Region. They weighed between 128 and 135 tons, so that the 106 tons of the "Deltic" (72 lb per horsepower) gave it the best power/weight ratio achieved in any diesel locomotive at that time. Indeed, this figure has only just been equalled in the 4000 h.p. diesel-hydraulic locomotives being supplied to two U.S. railways from Germany. It may be recalled that the original "Deltic" was designed and built as a private venture by The English Electric Company, Ltd., and offered to British Railways for trials. The locomotive was described in THE ENGINEER of October 21, 1955, page 571. In 1958 British Railways ordered twenty-two similar locomotives for service on the East Coast main line between London, Leeds and Edinburgh. They are now entering service, and when the winter timetables become effective will enable considerable improvements to be made in passenger train schedules. They rank as type-5 in the British Railways power classification.

The weight of the new "Deltic" locomotive has been brought down to 99 tons (although carrying 900 gallons as against

Fig. 1—One of the 3300 h.p. diesel-electric locomotives now being allocated to the Eastern, North Eastern and Scottish Regions of British Railways

800 gallons of fuel), partly as a result of fitting shorter bogies with a wheelbase of 13ft 6in instead of 14ft 4in. Bogies and suspension are identical with those of the English Electric type-3 diesel-electric locomotives described in our June 23, 1961, issue, page 1040. This change has increased the availability of the " Deltic " class, enabling it to operate over lines from which the prototype was barred because its longer bogies infringed certain platform clearances. Bogie centres are now at 45ft instead of 44ft, and the length of the locomotive over buffers has been increased from 67ft 9in to 69ft 6in. Overall width remains at 8ft 9½in, but the contours of the body sides give somewhat greater freedom of movement in the engine-room. A further gain in this respect comes from the extensive use of " Fibreglass " ducts to house cable runs, while the whole interior layout has been much improved from the point of view of accessibility of equipment. " Fibreglass " is also used for battery boxes, sand boxes, instrument panels and doors, and cables are in aluminium conduit. These developments combine with further use of light alloy sections in achieving the saving in weight mentioned above.

The locomotive characteristics have been modified to give slightly higher tractive efforts at the top of the speed range—10,800 lb at 90 m.p.h. and 10,000 lb at the maximum service speed of 100 m.p.h. Continuous tractive effort is now 35,000 lb at 32·5 m.p.h., compared with 23,400 lb at 43·5 m.p.h. in the prototype. Three traction motor weak-field steps are available by field-diversion, but the third is only operative if the locomotive is working on one of its two engine-generator sets. This enables full tractive effort to be developed, although at half voltage and lower road speed. Oil servo load regulators have replaced the electrically driven ones of the prototype and are here used for the first time in conjunction with " Deltic " engines. Either load regulator initiates field-weakening when driven to its maximum excitation position and causes the other to do the same simultaneously. Each weak-field step is taken direct without reducing excitation, but in notching back to full field, under the control of a current relay, the regulators unload and then run up again.

Originally the controller had an intermediate position marked " 1 " on the quadrant between " off " and " full power " During movement to this position the engines ran at idling speed, but the motor contactors were closed on the first movement of the handle and the main generator field was built up. In the present locomotives no intermediate position is marked ; the first 20 deg. of movement of the handle from " off " are concerned only with selecting circuits while the engines continue to run at their idling speed of 650 r.p.m. Further movement of the handle closes the motor contactors and accelerates the engines, simultaneously bringing the load regulators into action to control the generator field excitation.

The driver has before him a main ammeter reading up to 2500A. There is no limitation on the current that may be taken within this range, but the overload protection would operate beyond it. This is not likely to occur above 5 m.p.h. Main generator current for the maximum tractive effort of 50,000 lb is 2400A, and the current when starting a train in average conditions is in the range of 1500A to 2000A. On the right of the cab (Fig. 2) is the instrument panel for the Spanner train heating boiler and the control lever of the water scoop for its replenishment. The boiler rating is 2000 lb of steam per hour.

Fig. 2—Cab interior, showing driving position on left and train heating boiler panel, with water scoop control, on right

The two power units in the locomotive are identical, each consisting of a Napier " Deltic " D18-25 eighteen-cylinder diesel engine developing 1650 h.p. at 1500 r.p.m., direct-coupled to an English Electric EE829A main generator with an EE913A auxiliary generator driven from the engine phasing gearbox. The main generator is a d.c., self-ventilated machine with a continuous rating of 1650A at 660V. The armature is directly coupled to the engine output shaft, at which the engine crankshaft speed of 1500 r.p.m. is stepped down to 1125 r.p.m. Compared with the prototype, the phasing gears have been modified to give this step-down in speed in order to improve the commutation. The armature coupling also forms the hub of the generator ventilating fan, and the opposite end of the armature shaft is supported in a single self-aligning roller bearing. In normal service the two main generators are connected in series and supply the six traction motors connected in three parallel groups of two motors in series.

Each main generator has an auxiliary generator mounted above it, driven by a take-off shaft from the engine phasing gearbox at 1⅞ times the engine crankshaft speed. This auxiliary generator supplies current at 110V for field excitation of the main generator, control, and auxiliary circuits, the load being shared by both generators when both diesel engines are running. If the locomotive is working on one engine only, however, the full auxiliary load can be taken by the one auxiliary generator.

Power is transmitted to the 3ft 7in diameter driving wheels by six axle-hung traction motors. These four-pole machines are identical with those in the type-3 locomotives to allow full interchangeability of bogies, but work at half the voltage in the latter, where they are connected in series-parallel across a single generator.

When the winter timings are introduced, one of the " Deltic " locomotives will work the 7.30 a.m. express from Leeds to London in 3 h and the 7.45 a.m. from King's Cross to Leeds in 3 h 10 min. This down service conveys a Sheffield portion which is detached at Retford, and the average speed of nearly 72 m.p.h. start-to-stop from Hitchin to Retford (106 miles) will be the fastest on British Railways. In the past the best time between King's Cross and Leeds has been 2 h 43 min down and 2 h 44 min up by the prewar steam-hauled streamlined train, the " West Riding Limited," introduced in 1937. This service was formed of eight-coach sets weighing 278 tons.

The locomotives will run as far North as Edinburgh, which is the longest round trip from London allowing diagrams to be planned for economic utilisation of this new motive power. A mileage of 6000 a week is envisaged, and it is intended that class " A3 " " Pacific " steam locomotives displaced from passenger trains by the diesels shall be transferred to fast freight workings. Eight " Deltics " each are being allocated to the Eastern and North Eastern Regions, and six to the Scottish Region.

On July 18 the new " Deltic " locomotive No. 9003 made a demonstration run from King's Cross to Leeds and back with an eleven-coach special weighing 382 tons. The down journey was allowed 189 min for the 185 miles 58 chains, and accomplished in 187 min with a stop at Peterborough. On the return run the time allowed of 185 min with the Peterborough stop was again improved on, the run being made in 182 min. Although point-to-point averages as high as 89·5 m.p.h. were called for by the schedules (Barkston South Junction to Newark, 10 miles 32 chains), the maximum speed on either journey was 93 m.p.h.

SUEZ CANAL INSPECTION.—A Marconi-Siebe Gorman underwater TV camera is to be used by the Suez Canal Authority to examine the underwater condition of the canal and the entrances to Port Said and Suez harbours and to provide more accurate control of dredging operations.

INTERNATIONAL CONFERENCE ON HEATING, VENTILATING AND AIR CONDITIONING.—An International Conference on Heating, Ventilating and Air Conditioning will be held in the Empire Hall, Olympia, London, from September 27 to October 4, and is being organised by the Institution of Heating and Ventilating Engineers. The Conference will discuss future developments and examine trends and review technical advances, administrative problems and the possibilities of greater integration in the work of specialists concerned with buildings. There will be three themes for discussion ; on theme 1, " administrative advances likely in the next ten years," eight papers will be given, while nine papers will be presented on theme 2, " technical advances likely in the next ten years." Five main papers will deal with various aspects of theme 3, " integrated design of architectural and engineering services for economy of building construction." In addition to the papers there will be a programme of technical visits linked with the three themes of the conference.

The River Crossens Drainage Scheme

A land drainage scheme affecting about 32,000 acres of rich agricultural land near Southport in Lancashire was inaugurated last Friday by H.R.H. the Princess Alexandra. The Crossens pumping station is the major engineering structure of the scheme, and is the third largest pumping station in the country ; it is shown in the two illustrations.

THE River Crossens catchment area forms roughly a semi-circle of 5 miles radius centred on Southport, which is itself situated on a coastal strip of sand dunes and alluvium. Landwards from this coastal strip is a low-lying basin, formerly a lake or mere. The natural outlet from this lake was at Crossens, and the present drainage channels, most of which are artificial, converge to this point. Most of the land surface is below the level of the highest tides, and doubtless formerly the sea occasionally broke into the freshwater lake. Rapid run-off from the high ground at Ormskirk and from the built-up area of Southport and Birkdale aggravate the drainage problems. The need for the scheme which is the subject of this article, and which is now nearly complete, arose from two main factors. On the one hand, the major part of the low-lying area of the scheme has a peat surface which gradually shrinks with cultivation and drainage, and on the other, a growing deposit of marine silt on the foreshore has raised the level of the estuary channel.

Since the first channel was cut at the end of the 17th century, the principal stumbling block to satisfactory drainage has been the mud and silt of Liverpool Bay which has consistently choked the outfall channel across the saltings, and in fact the accumulation is now such that the foreshore from High to Low Water is some four miles across. Originally the whole area was drained by gravity to the Crossens Channel at Crossens, and this arrangement worked until approximately the middle of the last century, when steam pumps were installed at Crossens, since when the central area of about 7000 acres has been drained by pumping, although the two areas on both sides of the central area—one known as Three Pools and the other as the Sluice—were still being discharged by gravity. The total area of both " wings " is about 16,000 acres.

As a result of the factors mentioned above, the area has been subjected to severe and frequent flooding, and it was decided that the whole area of about 23,000 acres should be pumped, although provision for some gravity discharge has been retained. The total area of benefit, however, is about 28,000 acres.

The scheme comprises three main sections :

(1) The cutting of a new channel about 4½ miles long, considerably improving the drainage of the central area which has been pumped for more than 100 years.

(2) Widening and deepening of the main channels in the Three Pools system and those of the Sluice system on both " wings."

(3) Construction of a new pumping station to house pumps capable of draining both " wings " and the central area.

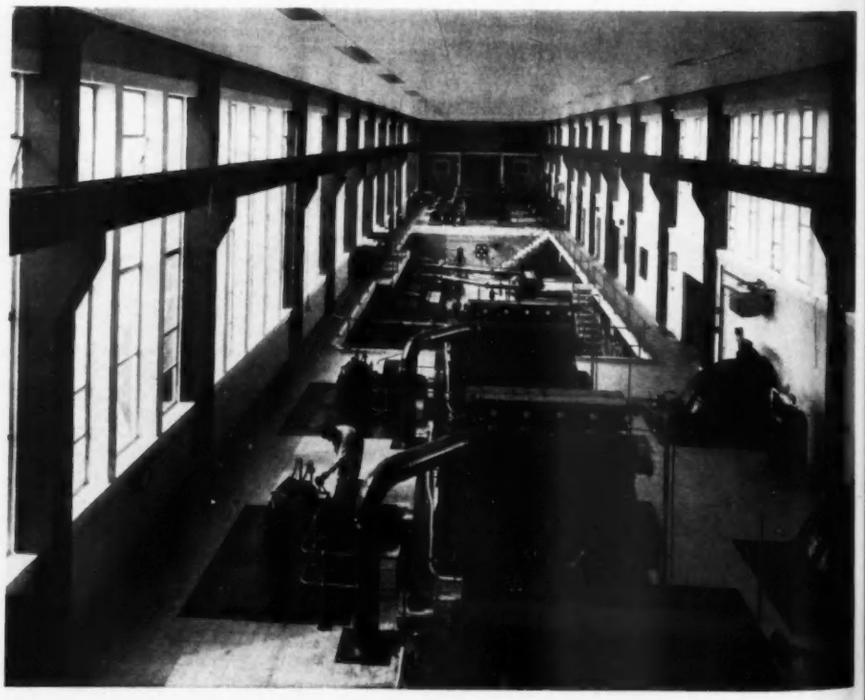
The work in sections 1 and 2 has necessitated the reconstruction of numerous existing bridges, construction of many new bridges, and the reconstruction of underdrains which drained the low-lying lands to the central system under the main rivers on both " wings." An interesting feature of the scheme is that the pumping station and bridge works have been constructed so as to allow for future deepening of the channels when the gradual shrinkage of the peat makes this necessary. Underpinning existing bridges (to a depth of 4ft to 5ft) has proved to be an expensive and hazardous job, owing to the difficult ground conditions and the need for the new channel bed to be well below the existing abutment foundation level. The pumping station has also been constructed to allow for a future increase in its capacity, should this be considered necessary.

Some principal data for the scheme are given in the Table. Most of the excavated material was spread on the fields by bulldozer, to a depth of 4in. The discharge capacity of the former gravity channels was more than doubled, and an entirely new channel cut in the middle area.

TABLE—*Data for the Crossens Land Drainage Scheme*

Catchment area	35,540 acres
Area of direct benefit	28,000 acres
Approximate cost of scheme ...	£1,000,000
Basis of channel design	0·5in run-off per twenty-four hours with 3ft free board
Previous capacity	0·3in run-off per twenty-four hours bank full
Length of channel excavated ...	32 miles
Total quantity of excavation ...	About 1,000,000 cubic yards
Number of new bridges	Thirty-five
Number of new culverts	Eight
Number of bridges underpinned	Twenty-five
Number of underdrains reconstructed	Nine
Total capacity of new pumping station	840 cusecs = 450 m.g.d. = 2,000,000 tons per day
Total horsepower of station ...	2,675
Dimensions of station	180ft by 40ft by 60ft

In some cases tributary streams draining to the lower middle area pass in pipes under the main drains of the other two higher level systems. The pipes of each of these crossings had to be lowered to allow the channel above to be deepened. Generally, this was done by thrust-boring, e.g. a 3ft pipe, 140ft long, was placed under a main road and the channel above in a matter of days, without disturbing road users.



Interior of Crossens pumping station ; the centrifugal pumping sets are in the central well. The heading illustration shows the rear of the pumping station from the Three Pools side

The Pumping Station

The new Crossens pumping station building is a large structure with reinforced concrete foundations in which are housed the pump intakes, etc., the superstructure frame being in precast reinforced concrete clad on the outside by brick walls and exposed aggregate panels. The window frames are of aluminium. The Southport–Banks road had to be diverted to construct the pumping station, and as a result a reinforced concrete sea wall was built to accommodate this road in front of the station. The station houses six 42in axial flow pumps of a total capacity of 630 cusecs driven by five-cylinder diesel engines, each developing 288 b.h.p. when running at 480 r.p.m., and driving the pumps through bevel gear boxes having a ratio of 1·37 to 1. The design head of these pumps is 12·5ft, and the discharge is through siphons fitted with siphon breakers. These pumps are housed on both " wings " of the pumping station in batteries of three. In the centre, at a lower level, are housed seven 24in double-suction centrifugal pumps driven directly by four-cylinder diesel engines, developing 129 b.h.p. at 339/465 r.p.m. The design head is about 16ft. The discharge pipes are closed by 24in hand-operated sluice valves. A thermostatically-controlled oil-fired boiler is installed for central heating ; electricity for lighting and driving small auxiliary pumps, etc., is supplied from the grid, but there is also a small standby diesel-engine-driven generator. A battery maintains essential electrical services during the short period until standby set takes the load. The seven 24in discharge pipes from the centrifugal pump sets and the discharge culverts from the axial pump discharge chambers pass under the road and through the sea wall across a pitched apron into the outlet channel.

All the axial-flow pumps went into commission between July and the end of September last year, and the centrifugal sets between July last year and March this year. Execution of the whole scheme commenced in February 1958 and it is now substantially complete and in operation, but some inland works remain to be carried out, including one large underdrain. The scheme will be completely finished by the autumn of 1961, but almost all the benefit has already been gained, the area having been spared the flooding which would certainly otherwise have occurred during last autumn and winter. The benefit of the scheme to the farmers is difficult to evaluate, but the known direct losses due to flooding were £140,000 in 1954 and £200,000 in 1956 ; the real value of the work may lie in the provision of better and more controllable conditions for agriculture.

The authorities sponsoring the scheme are the Lancashire River Board and the River Crossens Drainage Board. The consulting engineers responsible for its design and for supervision of construction are Messrs. C. H. Dobbie and Partners. The main contractors are, for the civil engineering, Norwest Construction Company, Ltd. (contracts valued at about £730,000) and Costelloe and Kemple, Ltd. (contract of about £80,000), and for the pumping station plant, Gwynnes Pumps, Ltd., for the six axial flow pumps and W. H. Allen, Son and Co., Ltd., for the seven centrifugal pumping sets.

Oil Tanker S.S. "Serenia"

THE first of three oil tankers of 66,000 tons deadweight has now entered the service of Shell Tankers, Ltd., under the command of Captain J. C. Nettleship, the Commodore of the fleet. " Serenia " was built at the Walker Naval Yard of Vickers-Armstrongs (Shipbuilders), Ltd., and engined by Vickers-Armstrongs (Engineers), Ltd., and her main employment will be the carriage of Middle East crude to Shell Group terminals in North West Europe, mainly at Tranmere for Stanlow and at Europort for Rotterdam. The main particulars of the ship are :

Length overall	817ft 9in
Length between perpendiculars	775ft
Breadth moulded	112ft 6in
Depth moulded	57ft 9in
Draught	42ft 10½in
Deadweight	66,790 tons
Gross tonnage	42,082
Service speed	16·5 knots
Power	22,000 s.h.p.

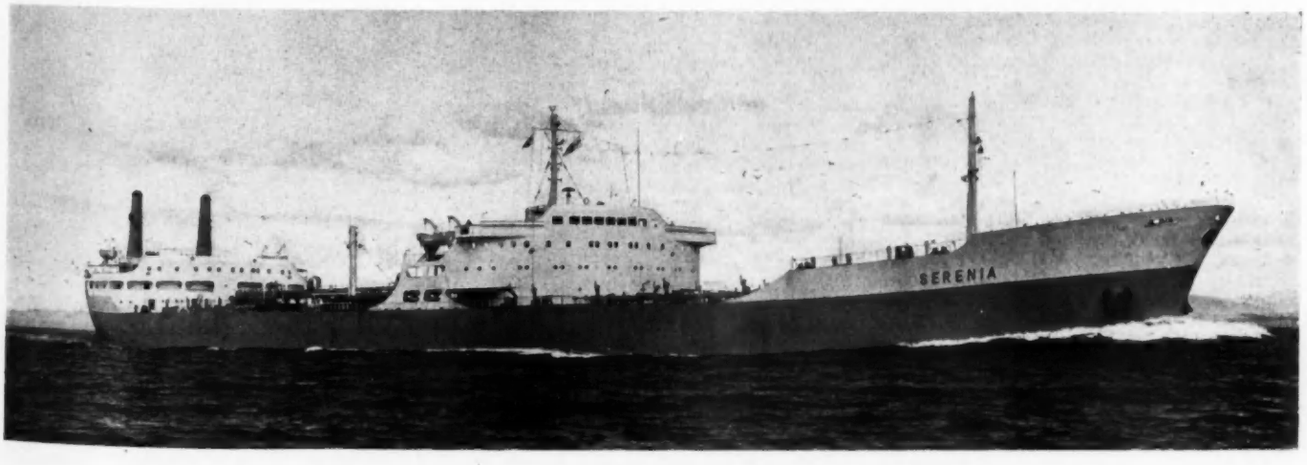
As can be seen in our illustration " Serenia " is of distinctive appearance with twin funnels aft. Construction follows oil tanker practice, including longitudinal framing, two continuous longitudinal bulkheads and a centre line wash plate bulkhead ; a fore and aft gangway which only runs between midships and the aft deckhouse is of new design using steel plate arched construction instead of lattice framed pattern. There are fourteen sets of cargo and ballast tanks and one main pump room ; there is no forehold or forward pump room, the fuel in the forward bunker tanks being transferred by submerged pumps driven by motors mounted on the forward peak flat. Of the forty-two compartments No. 1 centre and Nos. 1, 8, 9 and 10 port and starboard wing tanks are used only for clean ballast amounting to about 14,550 tons of sea-water. The remaining tanks have sufficient capacity to load the ship down to her tropical marks with crude oil of 0·82 specific gravity. All permanent ballast tanks have two coats of epoxy coal tar paint to prevent corrosion, and for the same purpose the remaining wing tanks have the deckhead and the top 5ft of the bulkheads similarly treated, while in addition they are cathodically protected by magnesium anodes.

In the cargo pump room, which is lighted by external mercury vapour lamps, there are six Hayward Tyler turbine-driven vertical spindle centrifugal pumps, four rated at 1900 tons per hour against a pressure of 120 lb per square inch, and two for clean ballast and rated at 200 tons per hour against a head of 30 lb per square inch. In addition are three 200 tons per hour J. P. Hall steam-driven reciprocating stripping pumps and a 150 tons per hour ballast stripping eductor. The cargo piping system consists of 18in. main lines with 16in centre tank and 12in wing tank sections, and for clean ballast there is a 14in main with 10in tank sections. The centre tank suction, valves are power-operated and the cargo tanks are fitted with aluminium bronze heating coils on a combined conical coil and grid system. For tank cleaning a turbine-driven centrifugal pump of 320 tons per hour capacity against a 420ft head is provided, and a heater capable of raising 1000 gallons per minute of salt water from 50 deg. to 180 deg. Fah. Two fans driven by 250 h.p. impulse turbines and each rated at 14,000 cubic feet per minute at 50in water gauge are used for gas-freeing purposes.

Comfortable accommodation is provided, there being suites for the captain and chief engineer with single berth cabins for the officers and for most of the remainder of the crew. Extensive use has been made of Formica-faced Marinite bulkheads, and serving the accommodation is a system of air conditioning, mechanical ventilation and heating. The Marconi International Marine Communication Company, Ltd., has supplied a comprehensive range of communication equipment and electronic aids to navigation. For mooring purposes there are a turbine-driven cable lifter and two capstans on the forecastle, with the machinery fitted at upper deck level, and two more turbine-driven capstans on the poop with the machinery located on the steering flat. Other deck machinery, all supplied by Clarke Chapman and Co., Ltd., includes one steam winch, and six semi-automatic self-tensioning steam winches.

Propelling and Auxiliary Machinery

Propulsion is by a single set of double-reduction geared turbines of Pametrada design, driving a five-bladed " Nikalium " propeller and developing 22,000 s.h.p. at 108 propeller r.p.m. when taking steam at 570 lb per square inch gauge and 880 deg. Fah. The double-casing ahead h.p. turbine has twelve single-row impulse stages and the double-flow ahead l.p. turbine has five single-row impulse stages followed by five reaction stages in each flow. An extension of the h.p. rotor carries a two-row impulse h.p. astern turbine and forming an integral part of the l.p. ahead rotor is the two-row l.p. astern



Turbine driven oil tanker " Serenia " of 66,790 tons deadweight for Shell Tankers Ltd.

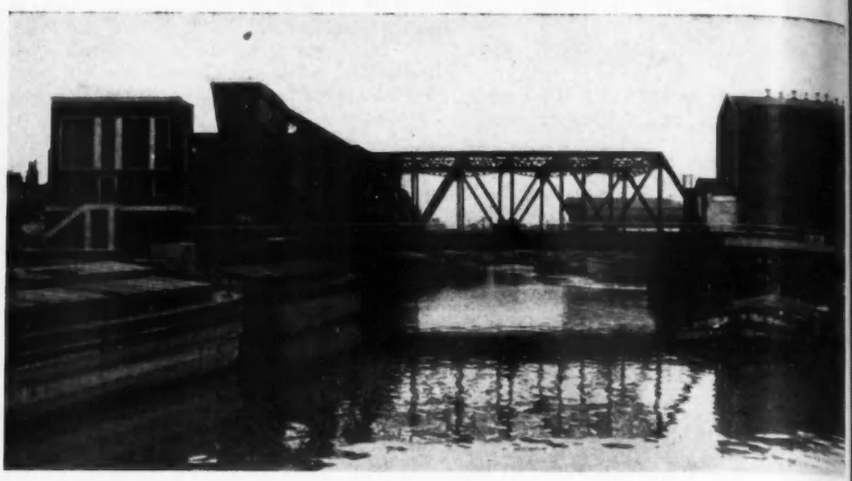
turbine to provide 11,000 s.h.p. when going astern. There is a two-flow twin regenerative condenser designed to maintain a vacuum of 28½in Hg with a sea temperature of 75 deg. Fah. and having a cooling surface of 15,100 square feet. Circulating water is supplied at 22,000 gallons per minute by a turbine-driven pump taking steam at boiler pressure, and there are two 160,000 lb per hour vertical motor-driven extraction pumps, for bringing the condensate up to 65 lb per square inch gauge, which discharge through the gland steam/air ejector condenser and the distiller of an evaporator to the deaerator. Drawing from the deaerator are two Weir turbine-driven centrifugal three-stage feed pumps, each capable of delivering 240,000 lb per hour at 740 lb per square inch gauge. The pumps take steam at boiler pressure and exhaust at 15 lb per square inch gauge to the low-pressure steam range.

Two Babcock and Wilcox "Selectable Superheat" water-tube boilers, fitted with welded superheater, stud tube economiser, cast iron gilled tube economiser and air heater, burn oil fuel under forced draught and generate steam at 600 lb per square inch gauge and 900 deg. Fah. at the superheater outlet. Each boiler, with feed water at 240 deg. Fah., has a normal evaporation rate of 80,000 lb per hour, with a maximum of 95,000 lb per hour, the heating surfaces of the boiler tubes, the superheater, the stud tube economiser and cast iron gilled tube economiser being 8957, 1950, 1443 and 5645 square feet respectively. The Wallsend Slipway oil burning installation includes two screw pattern pumps, each able to discharge 15,000 lb per hour of Bunker "C" fuel at 450 lb per square inch, and three steam fuel oil heaters, any two of which will heat 14,000 lb per hour of oil from 100 deg. to 300 deg. Fah. The burners are designed for both pressure jet and steam assisted atomisation and give a turn down ratio in excess of 6 to 1. An automatic combustion control system is installed and forced draught is maintained by two Howden fans, each having a capacity of 32,000 cubic feet of air per minute against 19ft 9in water gauge.

An external desuperheater is fitted and an automatic control of steam temperature is achieved by a thermostat which adjusts the quantity of spray water. Safeguards include a complete shut down should there be a failure of operating air, and a shut down should output temperature exceed a safe limit. An auxiliary condenser handles the exhaust steam from the cargo pump turbines and from the deck and other auxiliaries. Lubrication of turbines and gearing is effected by two pumps each supplying 500 gallons per minute against a pressure of 45 lb per square inch, and the system includes two oil coolers each capable of cooling 500 gallons per minute of oil from 135 deg. to 110 deg. Fah. when supplied with sea-water at 75 deg. Fah. To provide distilled water there are installed two Weir single effect sea-water evaporating and distilling plants operating on exhaust steam at 10 lb per square inch gauge and designed to produce 3500 lb and 5500 lb per hour of distilled water respectively. A foam fire-fighting system has been fitted, in addition to normal equipment, to protect the boiler-room, pump room and deck, and foam from a storage tank pressurised to 100 lb per square inch gauge is forced through mains through spreaders, branches or monitors.

To meet electrical demands there are two 600kW turbo-alternators, manufactured by W. H. Allen, Sons and Co., Ltd., which use steam at boiler pressure. Each alternator is driven at 1800 r.p.m. through single-reduction gearing, and the turbines exhaust at 15 lb per square inch gauge to the low-pressure steam range so that condensers and associated equipment are not required. A 125kW alternator driven by a six-cylinder, four-stroke direct-coupled diesel engine has been provided for emergency purposes.

LONDON HEADQUARTERS OF ENGINEERS.—The John Thompson Group of Engineering companies, embracing some twenty-nine units, has centralised its London sales organisation in a new headquarter building in Tavistock House East, Woburn Walk, Dukes Road, W.C.1. In a room in the new offices is a photographic display and models which illustrate the many and diverse engineering activities of the group.



Drypool Lifting Bridge, Hull

EARLIER this month the new Drypool bridge was opened at Kingston upon Hull. The bridge carries the A165 over the River Hull and is one of the two main connecting links between the west and east sides of the city, and is the most southerly of the six bridges in the city.

The old bridge which it has replaced was erected in 1888, and was a hydraulically operated bob-tailed rim bearing swing bridge, having a roadway width of 15ft 9in. The old bridge had been carrying loads greatly in excess of those for which it could have been designed. The material of the old bridge was wrought iron and not steel and it was certain that the stresses induced in its members were in excess of what are considered to be permissible ; furthermore it was estimated that these members had been subjected to approaching 500,000 reversals of stress, and it was fairly certain that much of the material was considerably fatigued and the elasticity of some of the members had been destroyed.

There was little choice in the type of bridge to be adopted as a replacement, the most suitable being a Scherzer Rolling Lift with overhead balance tank, as shown in the accompanying illustration of the new bridge.

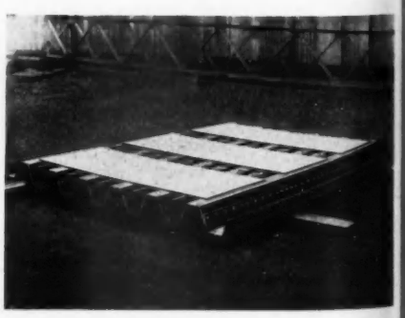
Aluminium alloy bascule bridges of recent construction, such as at Sunderland and Aberdeen, are much smaller in all dimensions and the design loadings are less than in the case of Drypool bridge. The design loading is in this case the Ministry of Transport "heavy abnormal loading," namely 180 tons on four axles. The very large forces induced in the members of the main trusses by this loading (some of which are of the order of 500 tons) would have necessitated light alloy members of very large section. In particular, the main cross girders (48ft 10in centres of main girders) would have been of great depth to keep the deflection within practical limits, and such girders could not have been designed within the limits of headroom stipulated. However, light alloy is used in the floor construction, which consists of aluminium alloy troughing with asphalt surfacing laid on light alloy plating. The main trusses and main load carrying members are of mild steel. A clear navigable waterway width of 80ft has been provided and, owing to the angle of skew of crossing, the main girders have a span of 105ft. The bridge has an overall width of 70ft comprising a 45ft roadway between kerbs with 8ft 6in wide footpaths cantilevered outside the main girders. The total rolling weight of the bridge is approximately 1800 tons.

The bridge rolls back on two quadrant girders of 23ft radius carried on track girders supported at the front ends on two cylinders sunk into the river bed, and at the rear ends on a piled mass concrete abutment wall. The nose end of the bridge at the east side of the river is supported by a fixed reinforced concrete approach span of open piling with beam and slab decks. The machinery houses on the west side of the river are of steel-framed construction faced with brickwork and carried on piled mass concrete foundations.

Two 135 h.p. motors operate the bridge, driving through gearing to the main pinions and operating arms. The machinery has been designed to work against a 5 lb per square foot wind in 1¾ minutes and a 20 lb per square foot wind in 2½ minutes. An emergency diesel unit enables the bridge to be fully opened or lowered in twelve minutes in the event of electrical breakdown.

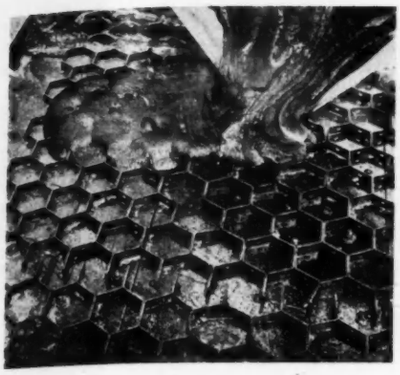
A cast-iron-lined tunnel of 8ft external diameter has been constructed under the river for the accommodation of mains cables and services.

The first constructional operation was the sinking of the tunnel shaft on the west side of the river and the driving of the tunnel eastward to a point beyond the new main cylinder positions. Cofferdams were then driven and the main river piers constructed in free air. Simultaneously, the east tunnel shaft was sunk and the rest of the tunnel driven westward and the abutment wall built. Following the founding of the river piers and the fixing of their bracing, proceeded the placing, levelling and fixing of the track girders, erection of the quadrant girders and ballast tank, the erection of the main span steelwork and the placing of sufficient kentledge to keep the span approximately in balance. The whole of this work was carried out with the bridge in the vertical position. With assembly of the operating machinery the opening span could be operated at slow speed at convenient periods of low water to allow erection of the decking.



Prefabricated light-alloy panel for the deck of the bridge

Demolition of the old bridge started in May, 1959, and work on the new bridge commenced on July 1, 1959. The bridge was designed by the



1in deep light-alloy mesh welded to the deck panels to key with the asphalt surface. The lower course of hot-laid asphalt is being placed in this view

City Engineer's department of Kingston upon Hull, the main contractor being G. Dew and Co., Ltd., and the steelwork sub-contractor Samuel Butler and Co., Ltd. The value of the main contract was about £620,000.

Electrical Equipment

All the electrical equipment for the bridge has been supplied by Associated Electrical Industies, Ltd.; variable speed a.c. commutator motors are being used for this application for the first time. These motors have constant speed over the wide torque range to which they are subjected by wind pressure on the bridge, and uniform rate of acceleration and deceleration under load ; from a starting speed of 100 to 1000 r.p.m. in fifteen seconds, and, when the bridge angle reaches 75 deg. from the horizontal —7 deg. short of its final raised position—from 1000 to 100 r.p.m. in fifteen seconds, at which point the mechanical brakes automatically cut-in and bring the bridge to a halt in the raised position. This system of combined electrical and mechanical braking costs less to service and maintain than a system of mechanical braking alone, it is stated.

Light Alloy Bridge Deck

The 40 tons of aluminium plate and section in the deck were supplied by Alcan Industries, Ltd. The aluminium is expected to have a longer life than alternative materials and to effect savings in maintenance. The decking is arranged in eight transverse bays between the steel cross-girders. Each bay is made up of five prefabricated panels measuring 9ft by 11ft 6in. The weight of each panel is about 2000 lb., each one being made up, as shown in the illustration, as follows : a series of trough sections in Noral alloy B51SWP (B.S.S. 1476 HE30WP) are first riveted together to form a corrugated profile 7½in deep with a pitch of 9in. Next, " I "-beam stiffeners, also in Noral alloy B51SWP, are fastened longitudinally in each trough on the upper side. Fastening cleats for this member are cut from a special extrusion and are riveted to the web of the beam and to the trough section. The prefabricated panel is completed with three ⅜in plates (Noral alloy B51S : B.S.S. 1477 HP30) which are bolted and riveted in position on the upper surface. They do not cover the whole panel in order to allow access for the final assembly. After the panels have been bolted into position the deck is completed by fixing the remainder of the plates.

All the aluminium components are painted with a bituminous paint. Strict attention has been given to preventing bi-metallic corrosion where steel and aluminium are in contact. A 1in deep aluminium hexagonal mesh is laid on the deck as a key for the road surface. This surface is a hot-laid mastic asphalt in two layers : the first, of pure asphalt, fills the mesh, while the second layer, which has pre-coated chippings rolled in, brings the overall surface depth to 2 ⅜in.

Furnace Research and Development

BECAUSE of the increased scope and volume of its work the Research and Development Department of A.E.I.-Birlec, Ltd. has been transferred from Tyburn Road, to larger premises, nearby, at Wood Lane, Erdington, Birmingham. The department itself was started nearly twenty-five years ago, soon after the formation of the company, and most of the time it has been sited at the firm's main premises in Tyburn Road. Its function is to carry out basic studies and development work on the company's products. For this purpose it is organised in four main sections dealing, respectively, with metallurgical processes, furnace design, gas plants and dryers and the testing of prototype equipment. Besides, some work is done for an associate company, Birlec-

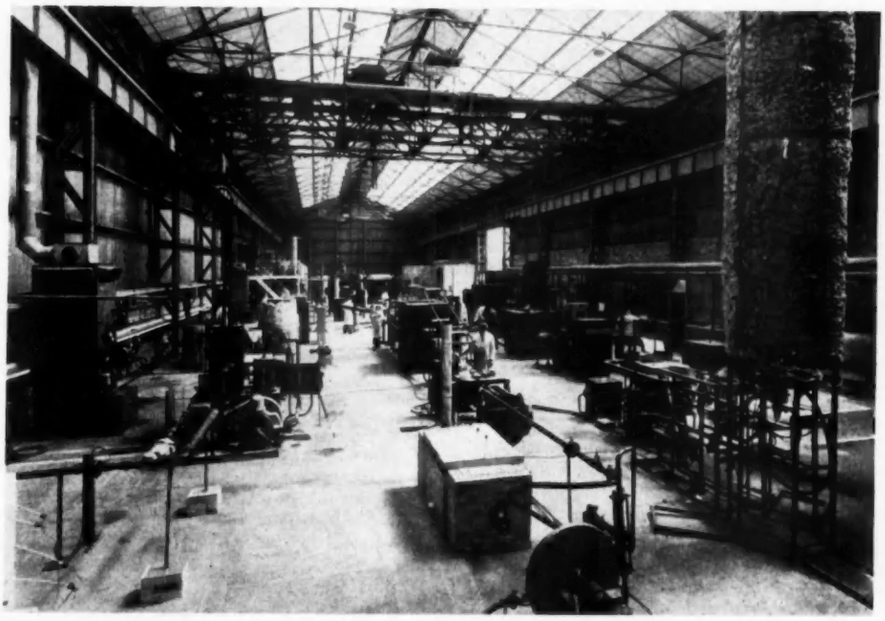
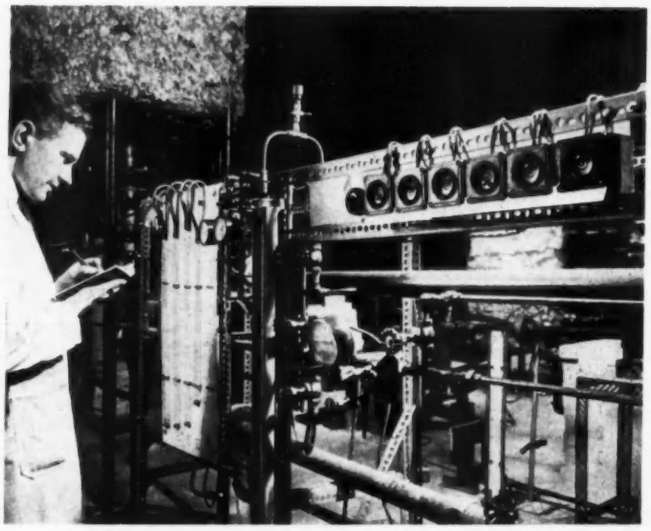


Fig. 1—Research and development department of A.E.I—Birlec Ltd. at Wood Lane, Birmingham.



Figs. 2 and 3—(Left) Adjusting the atmospheric seals at the discharge end of the new furnace for annealing stainless steel strip. (Right) Experimental rig for oil-fired radiant tube

Efco Melting, Ltd., on behalf of which a pilot smelting plant is operated near Aldridge.

The new laboratory is housed in a building 275ft by 70ft wide (Fig. 1) which, including a balcony, provides a total floor area of 20,000 square feet. An overhead crane of 10 tons capacity, with a 24ft lift serves the whole area. Thirty people are employed in the department ; about half of them have technical qualifications in physics, metallurgy, chemical, mechanical or electrical engineering.

In the building there are rooms for the preparation of metallurgical specimens, microscope and photographic work. Instruments available include infra-red gas analyser, Hersch oxygen analyser, Foxboro dewpoint measuring and control units and a "moisture monitor" dewpoint instrument. A Vickers projection microscope is also available.

Work in Progress

Below we give a brief outline of some of the work we saw in progress, during a recent visit to the new Research and Development Department.

Experimental Furnace, without Muffle, for Bright Annealing Stainless Steel Strip.—Bright annealing is done in an atmosphere of cracked ammonia and the usual annealing equipment incorporates a heat resisting nickel-chrome alloy muffle to prevent contamination of the gas. The muffle is expensive and for many applications will need to be replaced from time to time. In addition, the heating elements are necessarily fitted outside the muffle and their duty is thus made arduous.

In the experimental furnace (Fig. 2) the metal muffle has been eliminated by lining the furnace chamber with refractory specially selected for its ability to remain in equilibrium with reducing atmospheres of low dewpoint at high temperatures. The furnace in the laboratory incorporates strip handling gear and experiments can be undertaken with strip up to 6in in width. Work has been carried out with austenitic, ferritic and martensitic stainless steels with satisfactory results in all cases. The method of adjusting the atmospheric seals at the discharge and of the furnace is shown in Fig. 2.

Extension of the new principle to other bright annealing applications is being considered.

Test Rig for Oil-Fired Radiant Tubes.—A 15ft oil-fired radiant tube for furnace heating is operating in a specially constructed test rig in the laboratory (Figs. 1 and 3). Objects of this work include the investigation of factors affecting temperature distribution along the length of the tube, the identification of operating conditions likely to lead to soot deposition in the tube, the design of a burner suited to radiant tube operation and the collection of operating data, from thermocouple and manometer readings.

Single-ended Gas-Fired Radiant Tube.—A radiant tube in which a proportion of the products of combustion is recirculated within the tube is under development. The objects of this work are reduction of temperature gradients along the length of the tube and the development of a gas-fired unit which is interchangeable with the standard Birlec electric radiant tube heating element.

Prototype Exothermic Gas Plant with Flame Failure Protection.—In this development an attempt is being made to reduce the cost and size of exothermic gas generators and to improve operation. A gas/air mixture is combusted in a tunnel-type burner and the product gas is cooled by being passed through a curtain of water. A plant capable of delivering 5,000 s.c.f.h. of exothermic gas is at present working in the laboratory.

The main objects of this work are the collection of data on the design and operation of the burner, demonstration of the efficiency of the direct water cooling unit and assessment of the quality of the product gas with regard to metallurgical applications. Various commercially available flame-failure-protection devices have been tested on the laboratory plant, with a view to selecting the unit best suited for incorporation in the production generator.

Removal of Carbon-Dioxide from Products of Combustion of a Gas/Air Mixture.—The firm already markets a standard range of stripping units of the kind in which carbon-dioxide is absorbed in an aqueous solution of mono-ethanolamine but work is in progress on the development of two possible alternative processes.

The first involves the use of a suitable adsorbent material and is similar in operating principle to the conventional gas drying equipment containing activated alumina. It represents a considerable simplification in stripper design and operation when compared with the more usual mono-ethanolamine type unit. The equipment in the laboratory consists of a large rig in which the capacity of the adsorbent has been determined in relation to conditions of operation and reactivation.

The second process being studied is that of the absorption of carbon dioxide in water at high pressure. An experimental unit has been built and tests are due to be started soon.

Other Investigations.—The characteristics of power arcs are being studied with a view to discovering possible methods of influencing their behaviour in arc melting furnaces. Electrical resistors of new alloys and configurations are being investigated in a search for improved performance from resistance elements in furnaces. Work is in hand on the development of improved catalysts for endothermic gas generators. The rate of oxygen diffusion into a controlled-atmosphere furnace against outward gas has been studied and experiments to test the validity of the theoretical predictions are in progress. Seals are being developed for use on the ends of a high-vacuum, continuous strip annealing furnace.

Production Inspection to Tool-Room Precision

GAS turbine aero-engines are manufactured in fairly small numbers to very fine limits. In such circumstances the provision of receiver gauges for the inspection of the complicated major castings would add appreciably to the cost of each engine. Moreover receiver gauges are not normally adaptable to new purposes, the information they give is very limited, and often line manufacturing tolerances on the gauge exceed those of the component.

To avoid the need for large and expensive receiver gauges and to overcome some of their limitations, a novel inspection technique has been evolved at the Sunderland works of Bristol Siddeley Engines, Ltd.

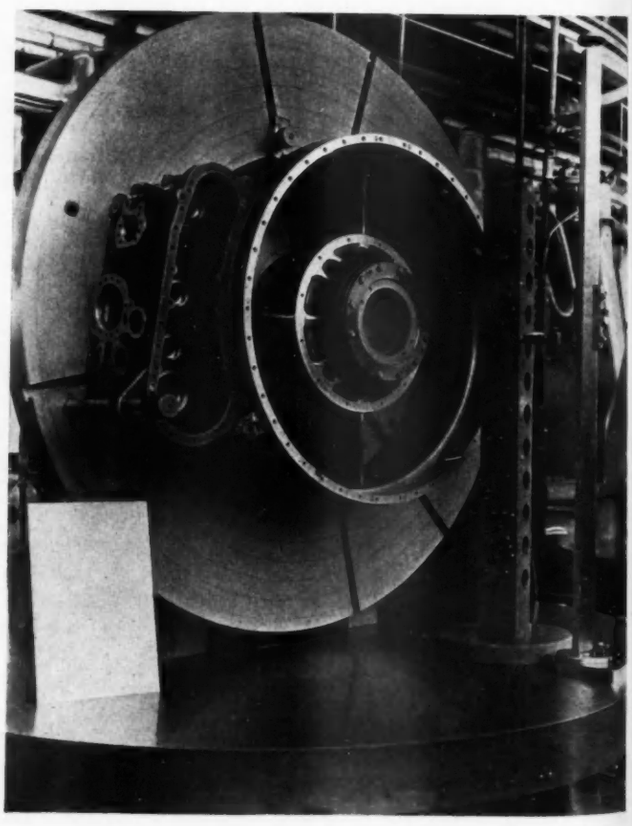
The equipment consists of a Pratt and Whitney 30in diameter vertical rotating table fitted with an adaptor plate 48in diameter and mounted on a circular surface table 5ft in diameter. The mounting incorporates packing blocks to accommodate the oversize face plate.

The rotating table is motorised and its angular position can be set to one second of arc. The surface table was manufactured for the purpose by Bristol Siddeley Engines, Ltd., and is permanently jacked at its centre to eliminate deflection caused by the weight of the rotating table.

The adaptor plate carries at its centre a 1in hole into which can be fitted an assortment of bungs which in turn locate in the centre bore of the component to be checked. This is particularly convenient for setting up the larger casings of gas turbines because they always have a bearing location in the centre and this is normally the main datum of the casing. The false face plate is also drilled to locate one other point on the casing to make the location positive.

The principle of the system is to measure the distance from the surface table to the bore of each hole which requires checking, on two ordinates at right angles. The dimensions are calculated from drawings and the constant dimension from the centre of the rotating table to the surface table. These dimensions can be set up using end bars and slip gauges, but for any quantity of components, setting pieces are made up from which all the dimensions for a particular inspection can be taken.

The setting piece consists of a relieved column with holes jig-bored at specified distances from the base. These distances are calculated so that nominally the top of a ½in diameter pin



Checking the co-ordinates of holes in the near face of an "Orpheus" compressor intake casing by reference to a setting piece. Notice, at the right, the supply of filtered air to the base of the height gauge

inserted in the hole will be at the required distance from the base. The holes are then calibrated in the standards room, after which compensation can be provided for any error in the position of a hole by adjusting the diameter of the exposed part of the pin which is to be made for it. For example, if a hole is found to be 0·0005in too low this can be corrected by fitting a pin 0·501in in diameter. The head of each pin is engraved with the distance from its top surface to the base.

By this method it is possible to produce a large number of dimensions on one setting piece to very close tolerances.

The dimensions are transferred from the setting piece to the component by means of a dial indicator reading in 0·0001in and mounted on a large height gauge, the base of which is pressurised from the air line to facilitate its movement on the surface table.

For each component there is a card-mounted procedure which details the settings for the rotating table and relates each dimension on the setting piece to the appropriate feature of the component to be checked.

As the bores and holes are checked for position by reference to their peripheries, it is first necessary to check them all for size. Holes with a limit of the order of 0·001in for position rarely have a tolerance on diameter greater than 0·0008in. This means that if the diameter of a hole is within limits the maximum error which can arise from checking its position by reference to its periphery is 0·0004in. Unless the hole size or position is on an extreme limit it is not necessary to take this into account.

The " Orpheus " air intake casing is a typical example of the components for which this equipment is used. It is first set up with its front face against the rotating table, located by a central bung which is a close fit in the bearing bore and by a pin which passes through a tooling hole and a corresponding hole in the face plate. The rotating table is then set to zero and a check carried out on the two compressor casing dowel holes near the horizontal centre line : they should be at the same distance from the surface table. If, owing to a small inaccuracy in the position of the tooling hole, this is not so, the attitude of the rotating table is adjusted until they are equi-distant from the surface table and the index reset to zero. In this position the dimensions from the surface table to all the bores and joint face dowel holes are checked. The casing is then rotated through 90 deg. and the process repeated.

The rotating table is then moved to an intermediate angle for a check on holes in faces on the side of the casing. Finally the casing is turned over for the inspection of bores which are only accessible from the front. The location of the tooling hole ensures that the correct angular relationship is maintained for checks carried out from the rear.

This equipment is versatile. It is being or has been used for three types of "Orpheus" air intake casing, " Orpheus " delivery casings, " Olympus " intake casings and " Proteus " intake and reduction gear casings. For all such components the basic equipment is the same. New components require only location bungs, one or two additional holes in the false face plate and, if the number to be inspected justifies it, a new setting piece.

The same equipment can also be used for stage inspections during manufacture. The " Orpheus " intake casing, for example, is checked three times—after the first machining operation, after the tooling holes and some dowel holes have been produced, and finally when all boring has been completed.

Unlike a receiver gauge, this equipment gives a quantitative result which is invaluable in deciding what action to take when an error has been found. The time taken to carry out a check on this equipment is no greater than that required for similar checks in a receiver gauge. When an error is found there is a marked saving in time because the nature of the error is clear and there is no need for the investigation which is necessary when a part has been rejected in a receiver gauge.

In view of these advantages the initial cost of the equipment is not high. It can show a considerable saving over more conventional methods if it is used for a number of different components.

A Folded Slab Roof in Precast Concrete

THE new bakery opened last week for United Bakeries at Fforestfach, Swansea, is a single-storey building of interest structurally because of the form of its precast concrete roof. It was required that : the building should be erected quickly ; there should be large areas of uninterrupted floor space ; there should be smooth surfaces internally which would be easy to keep clean ; the building should be well insulated; fire risks should be low ; provision should be made for future extensions ; and the maintenance costs generally should be low. Precast concrete folded slabs were used for the roof. The slabs are made into two types of " V " unit, both precast on the site, lifted into position and jointed to form the " V " roof and the " W " roof.

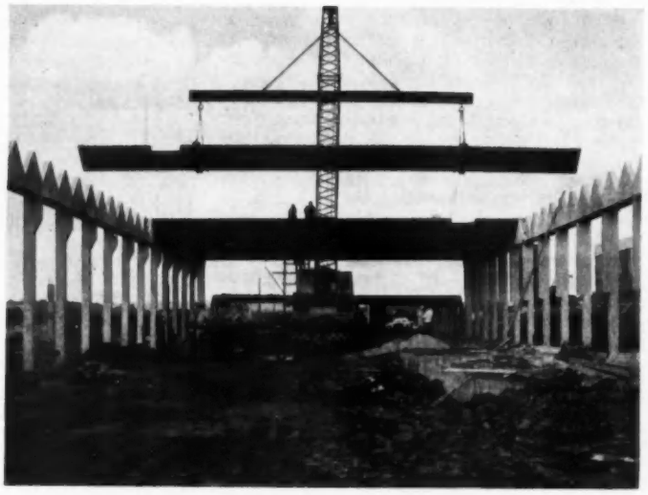
Each " V " unit consists of two pretensioned concrete slabs 2in thick, 3ft 7in wide and 67ft 8in long. The slabs were cast in a horizontal position on a stressing bed. The sides of each slab were castellated and had projecting loops of mild steel ; pairs of lifting lugs were cast in with the slabs. With the aid of a purpose-made steel truss, the slabs were lifted into a wooden cradle which set them at 45 deg. to form a " V " shape. Mild steel bars were then threaded through the projecting and interlocking loops —as shown in the diagram—at the base of the " V," and the valley joint was cast. At each end of the valley, a 3in diameter rainwater pipe of pitch fibre was cast in ; galvanised ferrules for fixing heating and lighting conduits were also cast into the valley at 50in centres.

The " V " units—each of which weighed about 6½ tons—were next lifted by mobile crane on to a bogie and taken into the building, where they were lifted into position on to the upstand parts of edge beams. This stage of construction is illustrated. Hollow rubber strips provided a flexible support for the slabs as well as a seal between slabs and edge beams. Finally, mild steel bars were threaded through the projecting loops at the ridges, in the same way as the valleys, and the joints were concreted.

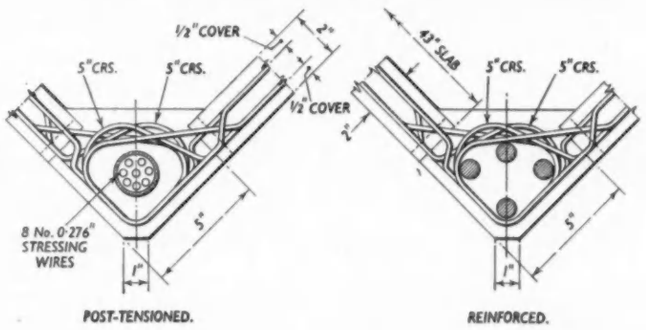
The " W " roof had the two outer wings of the " W " shortened so that a roof light of patent glazing could be fixed between each unit. It was cast and erected in exactly the same way as the " V " slabs except that the valley joints were post-tensioned.

These two types of roofing unit can be used for spans of up to 100ft. One unit per day was made on the site. Resistance time to collapse in the event of fire would be about one hour, it is considered. The fair-faced soffit to the concrete slabs obviated the use of a false ceiling. The slabs are watertight, the valleys forming the rainwater gutters. No expansion joints were required ; the roof folds or unfolds according to temperature change and the joints are designed to allow for this.

The structural consultant for the building is Mr. Felix Adler, A.M.I.Struct.E., and the main contractor Richard Costain (Construction), Ltd.



Lifting a V-shaped roof unit into position



Precast folded plate roof ; sections through valley

THERMOMETER WITH SIMPLE CALIBRATION.—A bi-metal thermometer designed for simple recalibration without need for skill has been produced by the British Rototherm Company, Ltd., Merton Abbey, London, S.W.19. This " Zero Re-set " thermometer has in the lower back of its vertical head a countersunk instrument screw stamped " RS—Re-set." Removal of this screw reveals the locking screw which is loosened by two turns to allow the thermometer stem to be rotated. This rotation of the stem moves the pointer, and by it adjustments of up to 50 per cent of the scale range can be made. A stop incorporated in the locking device prevents damage to the instrument. This thermometer is at present made with 2½in, 4in and 7in dials in the vertical pattern in all standard temperature ranges, and we understand that horizontal models will be available shortly.

SHORTER REPORTS

Institution of Mining Engineers

THE summer meeting of the Institution of Mining Engineers was held at the University of Nottingham last week ; the programme was largely arranged by the Midland Counties Institution of Engineers. In addition to the presentation of two papers for discussion the members were given opportunities to visit a number of mines and works in the Nottingham area and see an exhibition showing a number of aspects of its work arranged by the Safety in Mines Research Establishment.

Of the two papers presented at the meeting, one entitled " The Related Technologies of Coal Production and Its Utilisation " was given by Dr. D. T. A. Townend and Mr. R. L. Brown ; the other, " The Interaction of British and Continental Coal-Mining Technique," was given by Ir. A. Hellemans. In the first paper the various uses of different types of coal in relation to mining production were discussed, and the main inland disposals of coal by size grade to power stations, coke ovens, gas works, railways, general industry and the domestic market summarised.

A brief description of current investigations within the British Coal Utilisation Research Association into medium-sized industrial boilers covered automatic operation using an improved chain-grate stoker together with integrated mechanical handling of coal and ash. It was contended by the author that coal could compete with oil only if industrial boilers could offer comparable amenities and labour saving, and he concluded that further advances in mechanisation of mines and automation of coal-using equipment could meet the challenge of other fuels only if production, preparation and use were linked together more closely.

In tracing the interaction of British and Continental coal-mining techniques Ir. Hellemans first dealt with the fundamental differences on both sides of the Channel, and pointed out that in the past the geological differences between the coal deposits led to a different start in Great Britain and the Continent. He said that in the technical inter-relationship between the two areas there were four distinct periods : from the start of coal-mining until 1890 ; from 1890 to 1927 ; from 1927 to 1945, and from 1945 until the present day. During the first period Great Britain was the leader and the Continent adopted British inventions and methods. During the second period, starting with the first introduction of power-driven machinery into the pits, there was virtually no contact between Great Britain and the Continent and developments resulted in a marked difference in mining technique. During the period between 1927 and 1945, which was overshadowed by the coal crisis and by World War II, contacts between the technicians from the mining areas on either side of the Channel became more frequent, but true interaction and cross-fertilisation of ideas started only after 1945.

Lloyd's Shipbuilding Returns

THE returns issued by Lloyd's Register of Shipping for the quarter ended June 30th, 1961, show that in Great Britain and Northern Ireland the work in hand was 241 ships of 1,614,062 tons gross compared with the highest post-war figure of 2,345,408 tons at the end of 1957. During the quarter the respective totals of tonnage commenced, launched and completed were 57 ships of 341,092 tons, 72 ships of 375,353 tons and 64 ships of 341,918 tons. Of the total under construction 48·5 per cent., or 40 ships of 782,963 tons, were oil tankers. Tonnage for export amounted to 38 ships of 310,262 tons, representing 19·2 per cent of the total, while tonnage building abroad totalled 693,471 tons. Work in hand abroad, excluding China, East Germany and Russia, totalled 1259 ships of 7,184,421 tons gross, the leading countries being Japan with 1,023,911 tons, Germany with 864,262 tons, and Sweden with 832,131 tons. Progress during the quarter included 461 ships of 1,688,491 tons commenced, 414 ships of 1,574,563 tons launched, and 424 ships of 1,621,694 completed. Oil tankers amounted to 203 ships of 2,818,190 tons gross and represented 39·2 per cent of the total being built. Tonnage for export was 3,111,353 tons or 43·3 per cent of the total under construction, the percentage for export for individual countries being Sweden 66·1, Netherlands 64·9, Germany 63·5 and Japan 45·2 per cent of the total building in that country. Throughout the world 1500 ships of 8,798,483 tons gross were under construction, of which the share of Great Britain and Northern Ireland is 18·3 per cent. Oil tankers at 243 ships of 3,601,153 tons represented 40·9 per cent of the total. Tonnage building for export totalled 3,421,613 tons, of which 16·1 per cent is being built in Sweden, 16 per cent in Germany, 13·5 per cent in Japan, 12·4 per cent in the Netherlands and 9·1 per cent in Great Britain and Northern Ireland. At the end of June 4,351,727 tons gross or 49·5 per cent of the tonnage under construction were being built to Lloyd's Register classification.

Diesel Train Depot at Bradford

HAMMERTON STREET depot, Bradford, in the North Eastern Region, was the first on British Railways to receive diesel multiple-unit trains, for the units were based there which operated the pilot scheme on the Bradford–Leeds–Harrogate route, in 1954. The depot, once a steam locomotive shed, has now been fully equipped for servicing and maintaining diesel cars and shunting locomotives. At present eighty-five diesel cars and nineteen diesel shunting locomotives are maintained at the depot, and a further sixty cars will be delivered later.

Facilities for heavy maintenance and interior cleaning of coaches have been provided within the main shed ; a new servicing shed, fuelling siding and stabling sidings are the only external additions that have been necessary. Three of the eleven sidings in the main shed have been partitioned off to provide a repair shop for heavy maintenance. These sidings have illuminated pits and can accommodate twelve diesel cars. The remaining sidings provide for cleaning the interiors of coaches and degreasing transmission gears. Diesel shunter maintenance takes place in the lifting shop used formerly for heavy repairs of steam locomotives, but diesel railcar maintenance can be accommodated when necessary. An annexe along one side of the shed has been remodelled as offices, staff amenities, and a training classroom with facilities for showing demonstration films and slides. All rooms are heated by a central heating system which burns oil recovered from the diesel engine sumps, and also heats the diesel repair shop and shunting locomotive shed.

The new servicing shed is 80ft in length and has been erected over a track with a 190ft pit which was already in existence. The building is open at both ends to enable diesel cars to progress through it for routine inspections, minor adjustments and repairs. Fluorescent lighting mounted on the walls is directed from either side at the engines on the power cars. Storage for lubricating oil and anti-freeze is provided by two 750 gallon tanks installed in an annexe, from which they are dispensed to the diesel units by mobile containers.

The fuelling siding, to which the diesel cars run after leaving the servicing shed, is equipped with five fuel oil dispensing points, each having a 20 g.p.m. fuel pump, protected by weather canopies. Six fuel oil tanks provide a total storage capacity of 38,000 gallons. There are also ten watering points alongside the siding for refilling overhead lavatory tanks and engine cooling systems, and concrete runaway troughing and drainage between the tracks facilitates the cleaning of car toilets. A carriage washing machine is situated on a line adjacent to the servicing shed and so arranged that all units leaving the fuelling bay are washed before passing out.

Xerographic Printing of Computer Output

THE first production model has been completed of the " Xeronic " printer for printing computer output on a paper roll by the Xerographic process. It will be used with an " Emidex 2400 " computer which is to be delivered to the Ministry of Pensions and National Insurance in Newcastle later this year. In the printer, which we illustrate, the computer output is written electronically on a cathode-ray tube screen, this visual image being copied on to the paper roll by Xerography. Simultaneously rule and headings are printed on the roll so that the data appear ready tabulated in the manner required. At present four different designs of form can be selected, but development is in progress on a new machine that will select from thirty-two forms.

Printing computer data by Xerographic reproduction of characters on a cathode-ray tube

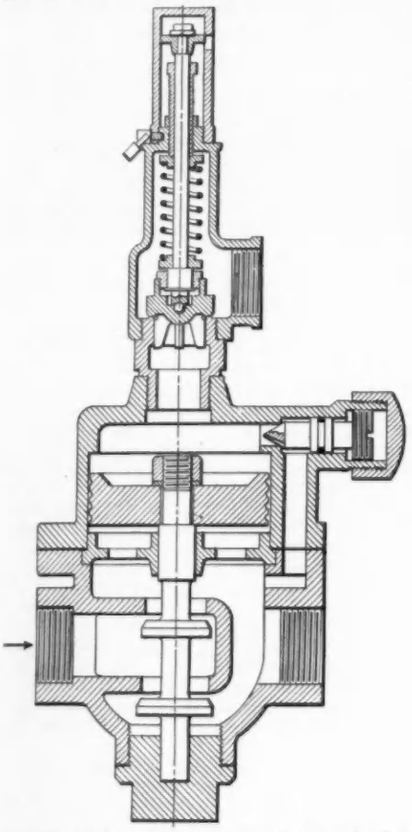
The " Xeronic " machine has been developed and manufactured by Rank Precision Industries, Ltd., 37–41, Mortimer Street, London, W.1. Printing is at the rate of 4700 characters a second, with no fast-moving mechanical parts. Further similar machines to be delivered this year are one to operate with a Ferranti " Orion " computer at the Ferranti computing centre, one for an A.E.I. 1010 computer in the R.A.F. Central Accounting Unit at Hendon, and a third to go to the Commercial Union Assurance Company Ltd., for use with an English Electric KDP10 computer at the data processing centre in Exeter.

[Reply Card No. 1112]

Excess Pressure Protection Valve

AN excess pressure protection valve for steam lines, which is being introduced by Sir W. H. Bailey & Co., Ltd., Albion Works, Patricroft, Manchester, is so designed that the steam supply is not shut off completely in an emergency, the downstream reduced pressure always being maintained at the set level so that process work, &c., is not interrupted.

The assembly, to be seen in the drawing we reproduce, includes a double-beat valve attached to a piston across which a pressure differential will be produced by any marked increase in inlet pressure. The piston is a loose fit in its cylinder and the valve is wide open under normal conditions. The effect of the differential is to lift the piston, which brings the main valve closer to its seating faces, so that the downstream line is automatically protected from excess pressure. As soon as the supply pressure returns to normal, the valve automatically resumes its original position.



Arrangement of excess pressure protection valve for steam lines

A relief valve at the top of the assembly is set to lift at a required safety pressure and deals with any minor pressure rise, but a severe rise will tend to close the main valve automatically whilst still maintaining a downstream supply at the preset reduced pressure. An adjustable needle valve is fitted into one side of the unit and the setting of the needle allows the performance characteristics of the valve to be matched to a specific application. It gives the valve flexibility of performance by controlling the amount of low-pressure steam allowed to by-pass the piston. If the needle valve is opened only slightly the main valve will regulate flow when the permissible pressure rise is small—this sensitivity tends to decrease with a wider opening of the needle valve.

This improved pressure protection valve is available, initially, in bronze, with screwed ends, to fit pipe sizes ¾in, 1in, 1¼in, 1½in and 2in. It can be fitted into a line with a normal working steam pressure of 150 lb per square inch, but in an emergency an inlet pressure of up to 300 lb per square inch can be accepted, whilst the spring ranges available are 2 lb to 10 lb, 10 lb to 80 lb, and 80 lb to 150 lb per square inch.

[Reply Card No. 1109]

Recent progress of the 34-storey tower block at Millbank, Westminster.

"Topping Out" at Millbank

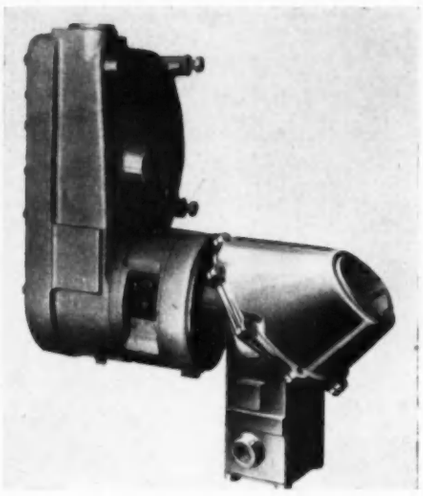
THE topping out ceremony for London's highest building—a 387ft high concrete structure—took place on Tuesday, July 18. The thirty-four storey building—which we illustrate—is part of the £5,000,000 Millbank development which also includes an eight storey office block, a twelve-storey block of flats, a three-tier parking garage, conference hall and restaurants. The tower block has an *in situ* reinforced concrete structure and prestressed concrete has been used extensively for the floors. The main occupiers of the tower will be Vickers, Ltd., and the topping out ceremony was carried out by the chairman, Viscount Knollys. The architects are Ronald Ward and Partners and the consulting engineer is Lieut-Colonel Kirkland of Messrs. R. Travers Morgan and Partners. The main contractor is John Mowlem & Co. Ltd.

Remote Monitoring of Storage Tanks

Two forms of a remote reading system for tank installations are announced by Whessoe, Ltd., Darlington, County Durham. The system is designed for use with Whessoe "S. and J." tank gauges or servo-operated gauges, but can also be fitted to the majority of tank gauges. It is complementary to the "S. and J. Telepulse" system and is suitable for large and small tank installations.

In its "Double Synchro 50" form the equipment is stated to have an accuracy better than ±1/20in (±1mm) to meet Customs and Excise requirements and is designed for storage transfer. This equipment comprises a weatherproof transmitter, mounted on the tank gauge as illustrated, which contains two synchro units; and a repeater, also containing two synchro units and including a dial gauge. The repeater is mounted on a panel in the central control station. This panel is usually also fitted with a selector switch enabling the dial gauge to show the levels of several tanks.

The two transmitter synchros are geared together to form a coarse/fine system and the fine synchro is connected to a sprocket in the gauge head, which is actuated by a perforated stainless steel tape connected to a float in the tank. Both synchros are electrically connected to the corresponding synchros in the repeater. Any change in tank level causes rotation of the sprocket and alters the angular position of the repeater synchros and of two coarse/fine pointers on a dial indicator. The coarse pointer indicates feet (or ½m) while the fine pointer subdivides this reading to an overall accuracy of 1/20in (1mm). All transmitters can be supplied with two separately adjustable limit switches which can be used for high and low level alarms.



Level transmitter fitted to automatic tank gauge

A feature of this equipment is that if the level changes on an unenergised transmitter, or if the power fails on a continuously-energised transmitter while the level is changing by more than a foot (or ½m), synchronism between transmitter and repeater is recovered when power is applied or restored, and the correct level immediately appears on the repeater dial.

The "Single Synchro 50" system has an accuracy of approximately ±½ per cent, suitable for the control of pumping. This equipment is similar in principle to the "Double Synchro 50," but its transmitter and repeater are each provided with only one synchro unit. The transmitter synchro is geared to the sprocket in the gauge head so that it never makes more than one revolution over the full tank height. The repeater synchro operates a pointer on the dial gauge.

All equipment is supplied in flameproof enclosures manufactured in accordance with B.S. 229/1957 for Group II and IIIA gases.

[Reply Card No. 1110]

Plastics Putty

A PLASTICS putty, which has been introduced under the trade name "Talurit" by Cable Covers, Ltd., St. Stephen's House, Westminster, London, S.W.1, has a very wide range of application in industry for repairing cracks, sealing holes or insulating electrical equipment and cables. This putty consists of two separate components—a resin and a hardener—which are supplied separately and can be stored without need for special air-tight containers or similar precautions other than being kept separate. When the two soft and malleable components are mixed together in equal portions they provide a readily workable putty which will adhere to any clean surface—metallic or otherwise. The putty is naturally self-curing in from one and a half to eighteen hours, according to prevailing temperature, and it attains a high degree of strength and hardness *in situ* whilst remaining dimensionally stable.

When set the putty can be drilled, tapped or otherwise machined without difficulty. Its strength and electrical insulating properties are supplemented by a high degree of resistance to water, oil and spirits, and it is stated to be completely innocuous. Independent tests quoted by the manufacturers give the following properties:

Compressive strength (ultimate) ...	11,200 lb per square inch
Tensile strength (ultimate)...	700 lb per square inch
Dielectric strength	253V/mil
Resistance between electrical conductors and armour	37,300 megohms
Resistance between electrical conductors and water	27,850 megohms
Water absorption	2·7 per cent

[Reply Card No. 1111]

SHORTER REPORTS *(Continued)*

Crop Spraying

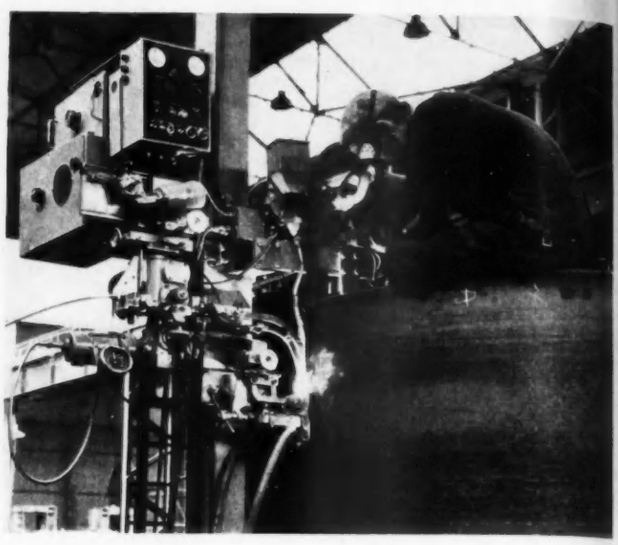
LAST week a demonstration was given at Luton Airport of a well-known design of light gyroplane, the Bensen, which is being developed by D. Napier and Son, Ltd., in conjunction with Pan Britannica Industries, Ltd., for aerial crop spraying. Collaboration between the two companies began some two years ago in an effort to determine the most suitable aircraft for the purpose. As a basis for development Napier bought a Bensen "gyrocoptor," choosing it for its positive advantages of simplicity, low cost and manoeuvrability, ease of transport, maintenance, and suitability for conversion.

The gyroplane has a McCulloch four-cylinder, two-stroke, air-cooled engine, which has a bore of $3\frac{7}{16}$in, a stroke of $3\frac{1}{8}$in, and a cubic capacity of 100 cubic inches. It develops 72 h.p. at 4100 r.p.m. The weight of the engine is 83 lb. Fuel consumption is at the rate of 4 gallons an hour, when spraying at a speed of 45 m.p.h., a mixture of petrol and oil being used.

The development gyroplane demonstrated was fitted with a 5-gallon capacity spray tank, although later, it was stated, it is hoped to fit a tank of 10-gallon capacity. An engine-driven centrifugal pump delivers the liquid to be sprayed to the 14ft spray boom, which can be seen in our illustration. With swirl atomisers fitted, Napier visualise using a centrifugal pump of 650 g.p.m. capacity at 50 lb per square inch pressure.

The gyroplane, which, it is stated, is essentially a farming tool, has now been handed over to Pan Britannica for operational evaluation both in static tests and in practical tests on the farm. At the same time, both Napier and Pan Britannica will carry out a comprehensive study into the operating costs of the gyroplane compared with fixed-wing aircraft.

Fixed-wing aircraft have certain disadvantages when used for crop spraying. The length of time taken in turning a fixed-wing aircraft at the end of a run is often considerably longer than the run itself. Furthermore fixed-wing aircraft operating at a minimum speed of 80 m.p.h. in the hands of experienced commercial pilots have had more than a tolerable number of crashes every season. Travelling at such a high speed and at a minimum safe height also adds to the danger of the spray drifting. Weather conditions which favour certain types of crop spraying are also often unfavourable in terms of their high incidence of non-flying days, and in many cases prevent crosscountry flying between base and the spraying area, where the weather may be perfectly suitable for flying.



Caisson sections being welded in a vertical position by automatic electro - slag welding machine

These are some of the many problems which face the originators of crop-spraying techniques and which, it is hoped, the gyroplane will overcome. The gyroplane can be towed on a trailer, which at the demonstration was towed behind a "Land Rover," from farm to farm. It can fly at low speeds and low heights without losing engine-out safety. It requires only a very short run for take-off and for landing. It is simple to refuel and refill with spray chemicals. It is adaptable to most spraying conditions, types and sizes of fields, and it is hoped that the operating cost will compare reasonably with ground spraying costs for small acreages.

Vertical Electro-Slag Welding Machines

WE illustrate one of two electro-slag welding machines which have been supplied to Swan Hunter and Wigham Richardson, Ltd., by the British Oxygen Company, Ltd., Bridgewater House, St. James's, London, S.W.1. These new "Subarc" machines are designed to automatically weld plates vertically and are being used for welding the seams in caisson sections, each 8ft high, 8ft diameter, and built up from two rolled plates $1\frac{7}{8}$in thick.

The welding head assembly is mounted on a carriage which travels up a vertical column at a speed controlled by a differential thermocouple system in accordance with the rate of weld deposit. The plates are positioned with a gap of about $1\frac{1}{4}$in between their square cut edges. For the welding operation water-cooled copper shoes are clamped on the inside and outside to form an enclosure with the plate edges. A special copper trough is placed at the bottom of the plate gaps for weld starting purposes, and this trough contains powder flux to blanket the weld pool when an arc is struck. As soon as this powder melts the arc is extinguished and heat for welding is thereafter provided by the passage of current from the welding wire through the molten slag. The seam is made by the continuous feed of wire melting on the slag, which also melts the edges of the plate, and as the metal is deposited the welding head and copper shoes move upwards at the automatically controlled speed.

In the application illustrated the speed of welding is about $\frac{7}{8}$in per minute and a seam is completed in under two hours, using some 70 lb of electrode.

[Reply Card No. 1103]

The Napier-Pan Britannica agricultural gyroplane research vehicle

Motor Vehicle Regulations

THE Minister of Transport has laid before Parliament new regulations pertaining to the maximum dimensions of public service vehicles and to the use of excess fuel devices on compression ignition engines.

From August 1, 1961, the maximum length of buses and coaches will be raised from 30ft to 36ft, and the maximum width from 8ft to 8ft $2\frac{1}{2}$in (2·5m); this will permit more foreign vehicles to enter this country, and render it easier to export British vehicles, as well as allowing more comfortable travel.

From January 1, 1961, it will be a requirement that any device designed to facilitate starting a compression ignition engine by supplying it with excess fuel shall be so maintained that it does not supply excess fuel while the vehicle is in motion on a road, and it will be illegal to use the device in those circumstances. On vehicles first registered after January 1, 1962, and on all vehicles after July 1, 1962, it will be a requirement that the device cannot readily be operated by any person while he is carried on the vehicle, unless the device is such that it complies with the previous requirement regardless of the user's commands. These regulations are, according to the Ministry of Transport, intended to reduce the nuisance caused by black smoke in vehicle exhausts.

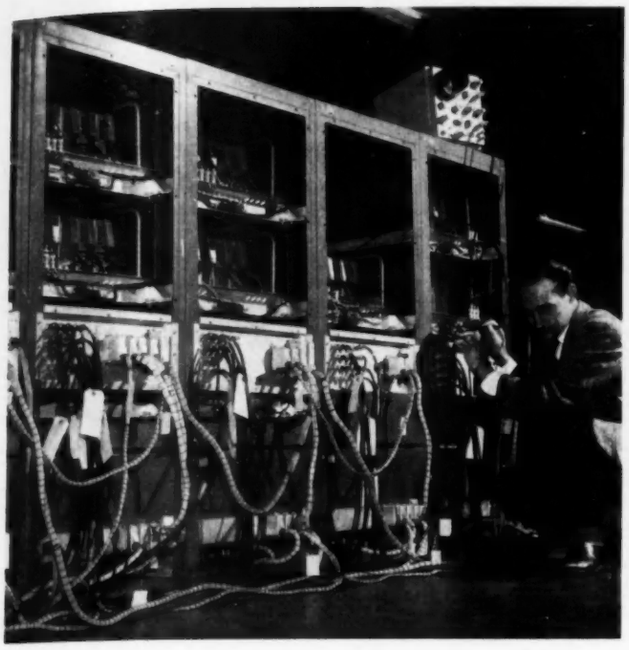


Fig. 1—Testing the circuits of a thermionic valve simulator for radar training

Fig. 2—Inserting the printed circuit cards of a transistorised radar simulator

Electronics Factory Opened

DEVELOPMENT at the Farnborough, Hampshire, headquarters of the Solartron Electronic Group, Ltd., has taken place in a two-phase programme. Completion of the second phase was marked formally on July 17 when the Rt. Hon. Reginald Maudling, M.P., President of the Board of Trade, opened a four-storey building which forms the main administrative, research, development and electronics manufacturing centre. Here on the ground and first floors are housed the Systems Research and Development Division and the Research and Development Division formerly at Goodwyns Place, Dorking. The second floor is a drawing-office area of 7000 square feet, while the third and fourth floors provide headquarters office accommodation.

The 70,000 square feet of workshop area contain the model shop for the research and development divisions, the transducer manufacturing section, the reading machine constructional section, the radar simulator assembly shop, the X-ray spectrometer manufacturing area, the analogue computer division and the Solartron electronic teaching and business machines.

A large area is devoted to the central wiring assembly section, which serves all the above interests. There are two extensive test sections, one concerned with the testing of products from the research and development departments before planning their production, and the other for testing manufactured products. There is also a training centre for wiring and assembly personnel.

Examples of Solartron products seen on exhibition after the opening ceremony included digital instruments (also widely incorporated in the company's own test gear), pressure transducers operating on the resistance bridge principle with strain gauges, computing and data handling systems, and radar simulators. Demonstrations were given of a thermionic valve simulator used with a precision approach radar console for training operators in talk-down procedure. Facilities can be provided for one operator to control two systems simultaneously and for several targets to be displayed. These equipments are constructed on a "building brick" system to allow flexibility in expansion and elaboration.

We illustrate in Fig. 1 a typical thermionic simulator in course of assembly, and also show in Fig. 2 a transistorised simulator which has now been developed. The latter can be housed in one pedestal of an average-size desk. There are close parallels between the techniques of analogue computing and of simulation, and by applying computer experience to the latter the saving in space illustrated has been achieved. A six-target device of the size shown has a basic power consumption of 20W per target. The circuitry has been planned so that only six or seven different printed circuit cards are needed in various combinations to provide the desired facilities. Test points are printed on each card for quick checking of circuit functions, and both the cards and the slots in the "nest" into which they are inserted are colour-coded. One of these simulators was demonstrated as a trainer for controlled interceptions. The small space and power requirements of these transistorised equipments make it practicable to present some forty targets on a p.p.i. display, as might be required for the evaluation of air traffic control schemes.

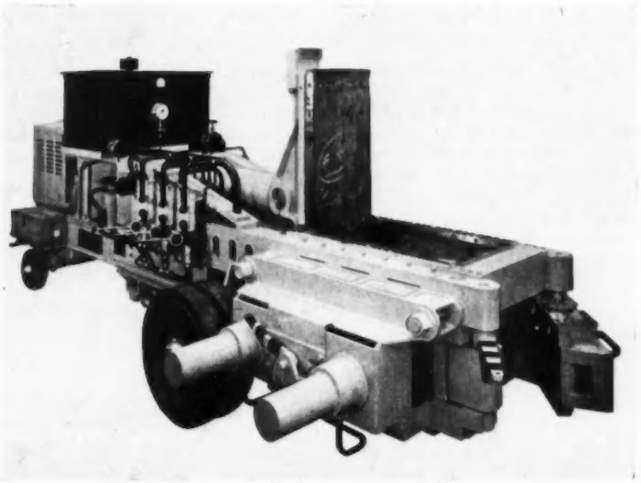
Mobile Scrap Baling Press

To facilitate the baling of scraps at strategic points in an industrial establishment without need for its transport in unwieldy bulk to a central point a mobile scrap baling press has been introduced by Fawcett Preston and Co., Ltd., Bromborough, Cheshire. This press weighing 15 tons is mounted on solid rubber tyred wheels and can be towed at speeds up to 2 m.p.h. between working sites. It produces bales of 1 cubic foot, weighing from 120 lb to 140 lb, at a rate of twenty to thirty an hour, according to the type of material and labour available.

The machine, illustrated below, is designed for the use of a 35 h.p. electric motor or a 40 h.p. diesel engine for driving the hydraulic pumps delivering pressure fluid to the rams used for the baling operation. The three rams used are controlled by conveniently situated lever-operated valves for the baling sequence. A 24in square by 50in long box is lined with renewable, wear-resisting plates, and reversible hardened shear blades are fitted to the lid sides and box edges to cut off overhanging scraps when the lid is lowered.

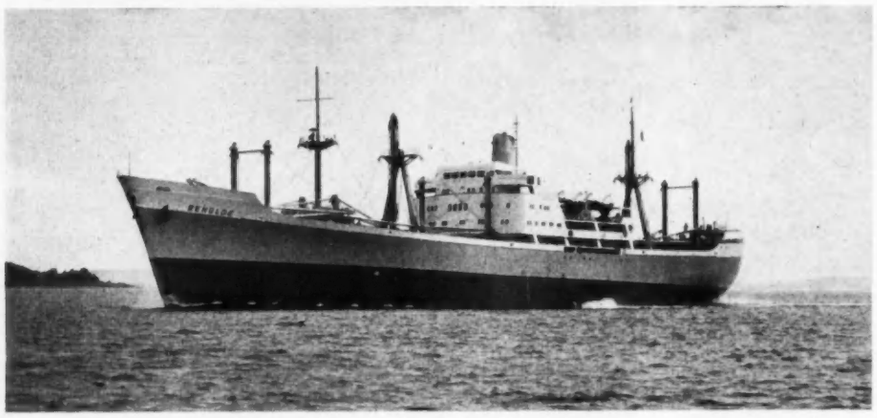
For the baling sequence the rear end door is closed and locked by a cam mechanism and the box is then filled with scrap. The trampling lid is forced down by its hydraulic ram upon operation of the first control valve lever, and when it is fully closed the size of the charge is reduced to 24in by 12in by 50in long. Upon the second control valve being operated, one box side is moved inwards by hydraulic rams to further reduce the charge size to 12in square by 50in long. When the valve of the main ram cylinder is then operated the ram moves forward to exert a maximum load of 100 tons on the scrap. When the maximum loading has been exerted the pressure on the main ram is released. The rear end door can then be opened and the main ram extended to eject the bale. The control valves are then operated to return the main and side rams and open the lid for the next loading sequence.

[Reply Card No. 1104]



100-ton mobile scrap metal baling press for producing 1 cubic foot bales weighing from 120 lb to 140 lb

SHORTER REPORTS *(Continued)*



Fast cargo line S.S. " Bengloe " of 13,290 tons deadweight for the Ben Line

Fast Cargo Liner S.S. " Bengloe "

THE second vessel of the " Benloyal " class, which has been specially designed for the Ben Line's Far East trade, has now sailed on her maiden voyage in the company's service. Built by Charles Connell and Co., Ltd., at its Scotstoun yard, the ship, named " Bengloe," seen on trial in our illustration, is similar in design and performance to " Benloyal," the name ship of the class, which was built at the same yard. Both ships have been engined by David Rowan and Co., Ltd., and the following are the main particulars of the new liner :

Length overall	549ft 7in
Length between perpendiculars...	506ft 9in
Breadth moulded	71ft 0in
Depth to upper deck	44ft 6in
Draught (summer)	33ft 5in
Deadweight	13,290 tons
Bale capacity	737,610 cubic feet
Gross tonnage	11,283
Net tonnage	6,556
Service speed	19 knots
Propelling machinery	14,000 normal s.h.p.

The " Bengloe " was launched on April 17 and is the fourth ship to bear the name, the first being built in 1878 and sold out of service in 1894, while the second joined the fleet in 1895. The third " Bengloe " was bought in 1920 and sold twenty-six years later. The fine lines of the tank tested hull form ensure an economical high-service speed allied with good sea keeping qualities, and the ship is due to arrive in Singapore twenty days after sailing from London and in Hong Kong eight days later. Except for the riveted seams at upper and lower turn of bilge and the upper deck stringer angle connection to the sheerstrake, the hull is completely welded, incorporating fabricated units up to 60 tons in weight. The liner has been built to Lloyd's classification and has longitudinally framed bottom and decks combined with a transversely framed hull. In way of accommodation the steel decks have been insulated and given a covering of composition instead of the traditional wood sheathing.

There is accommodation for ten passengers in addition to a crew numbering sixty and it is fully air conditioned throughout, the necessary equipment being supplied by the Winsor Engineering Marine, Ltd. For the passengers there are well furnished single and two-berth cabins, (each with toilet facilities), a lounge and cocktail bar. Complete suites are provided for the captain and chief engineer, and both the chief officer's and second engineer's cabins have bath rooms attached. The dining saloon has round tables to seat thirty-two and a ceiling embodying a laminated module lighting system. In both the the officers' smoke room and crew's recreation room television sets have been installed.

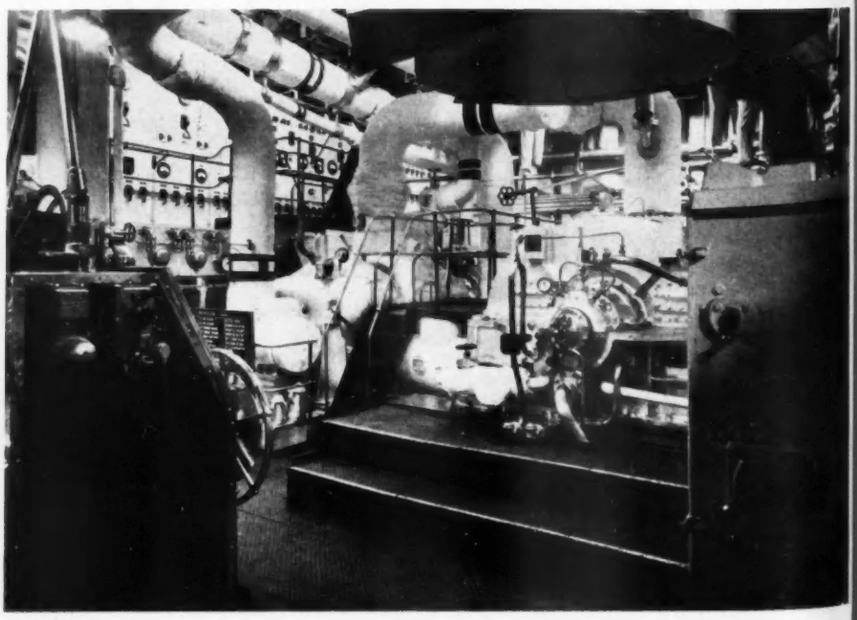
For the carriage of cargo there are four holds forward and two aft of the superstructure with additional space available in the poop. MacGregor single pull watertight steel covers are fitted to the weather deck hatches and the holds are ventilated by the Thermotank "Drihold" system and, together with the main machinery spaces, protected against fire by a Kidde-Rich CO_2 fire extinguishing and smoke detecting system. Serving the holds are ten 5-ton and ten 10-ton derricks and in addition there are two 5-ton Clarke Chapman electric cranes, while for heavy lifts there is a 70-ton derrick rigged at the main mast and one 50-ton derrick at the mizzen mast, both the masts being of self-supporting bipod design. For operating the derricks there is a complement of Laurence Scott electric winches, while for handling the 2¼in " Floryt " steel stud link chain cable, Clarke Chapman and Co., Ltd., has supplied an electric windlass and stoppers. Latex and edible oils are carried in eight tanks having a total capacity of 40,840 cubic feet and the oils are kept at the required temperature by an external heater and a circulating pump. For refrigerated cargoes there are four compartments on No. 4 lower 'tween decks, with a capacity of 14,800 cubic feet, served by fully automatic electrically driven refrigerating plant manufactured by L. Sterne and Co., Ltd.

Galley equipment was provided mainly by The Carron Company and the life-saving gear consists of glass fibre boats supplied by William Weatherhead and Sons, Ltd., and Mechans, Ltd., and carried under Welin-MacLachlan davits. Brown's electric hydraulic steering gear is fitted and controlled by automatic pilot from the wheelhouse, and navigation aids include Marconi equipment, Decca navigator, Kelvin Hughes compasses and Arma Brown gyro gear.

A single set of Pametrada designed, double reduction geared turbines, built by David Rowan and Co., Ltd., form the main propelling unit and develop 14,000 normal shaft horse power at 105 propeller r.p.m. and a maximum of 15,500 s.h.p. There is one h.p. impulse turbine and a dual flow reaction l.p. turbine, and for astern manœuvring there is a two-row impulse wheel h.p. astern turbine housed in a separate casing overhung at the forward end of the h.p. ahead turbine, and a two-row impulse l.p. astern turbine housed in a separate casing in the l.p. ahead unit. Astern power available is 8400 s.h.p. The turbines, which drive a " Novoston " propeller through a set of double reduction articulated gears, manufactured by the Fairfield Shipbuilding and Engineering Company, Ltd., are controlled from a centrally placed console. Our illustration of the engine-room shows the h.p. and l.p. turbines and part of the control console.

Two Babcock and Wilcox integral furnace, "Selectable Superheat" water tube boilers supply steam at 600 lb per square inch and 850 deg. Fah., and burn oil fuel under Howden's forced draught system. There are two sets of Babcock and Wilcox oil burning equipment. A G. and J. Weir closed feed system is fitted and includes a regenerative two-flow condenser constructed by the engine builders and underslung from the l.p. turbine, a closed-feed controller, a three-stage air ejector, two condensate extraction pumps, feed heater, drain cooler and two turbine-driven centrifugal boiler feed pumps. A Weir steam/steam generator provides steam at 100 lb per square inch for heating and domestic purposes when at sea, and this duty is performed in port by a Cochran vertical boiler. Boiler make-up feed is provided by a Weir evaporator and distiller. Pumps are mainly of Drysdale pattern powered by Allen motors. To meet the demands for electrical power there is a 400kW, 220V Allen generator powered by Bellis and Morcom self-contained turbine unit taking steam at full boiler pressure and three Allen 200kW generators, each driven by a Ruston and Hornsby diesel engine. H. T. Robinson and Co., Ltd., provided the switchboard of dead front design.

Including 95 tons of diesel oil, the ship has a total bunker capacity of 1670 tons and there is also tank capacity for 317 tons of boiler feed and fresh-water and for 360 tons of water ballast.



Looking aft in the engine-room

INDUSTRIAL NEWS

Export Credits

The Export Credits Guarantee Department has announced that the number of short-term policies current at the end of the second quarter of 1961 was 5537, compared with 5398 at the beginning of the quarter, and 4996 at the end of the corresponding quarter last year. The face value of short-term policies current at the end of the quarter was £777,200,000, compared with £759,500,000 at the beginning of the quarter, and £673,600,000 at the end of the corresponding quarter last year.

New medium-term business to the face value of £13,100,000 was transacted during the quarter, compared with £29,600,000 in the previous quarter and £39,300,000 in the corresponding quarter last year.

The gross value of all short-term and medium-term insured business, including external trade, declared as shipped during the quarter amounted to £189,200,000, compared with £194,800,000 in the previous quarter and £161,600,000 in the corresponding quarter last year.

Overseas Trade

The Board of Trade's latest assessment of the overseas trading situation is that United Kingdom exports in the second quarter of 1961 were 1 per cent less than in the first quarter, on a seasonally adjusted basis. The Board suggests that this fall can probably be accounted for by the inclusion in the figures for the first quarter of some goods delayed by the tally clerks' strike at the London Docks in September and October last year, and, in addition, some of the goods delayed by the strike in April and May this year may not have been included in the June figures. On the other hand, the Board adds, exports of ships, which fluctuate widely, were low in the first quarter and unusually high in the second quarter. Taking these factors into account there was probably very little change between the two quarters in the level of the underlying trend.

The seasonally adjusted fall of 1 per cent, £4,000,000, between the first and second quarters in exports of engineering products would have been greater, the Board says, but for an increase of £29,000,000, not seasonally adjusted, in exports of ships. Exports of machinery and instruments fell by 5 per cent, the fall appearing to have been mainly in non-electric machinery including tractors. Exports of tractors and parts in the second quarter were 2 per cent less than a year earlier, exports of boilers, boiler-house plant and steam engines were 10 per cent more than a year earlier, machine tool exports increased by 9 per cent, textile machinery by 10 per cent, mechanical handling equipment by 4 per cent, excavating machinery by 24 per cent, internal combustion engines by 11 per cent, and office machinery by 10 per cent. Exports of electric machinery in the second quarter were 11 per cent greater than a year earlier, but exports of generators and motors were 15 per cent less than a year earlier in the second quarter. Exports of scientific instruments continued, as in the first quarter, 13 per cent more than a year earlier. Exports of road vehicles and parts, seasonally adjusted, fell by 8 per cent between the first and second quarters. Aircraft exports were 16 per cent more than a year earlier, but there was no change between the first halves of the two years.

The underlying trend in imports, the Board states, has been falling since about the end of the third quarter of last year, although the effects of last year's dock strike prevented it from being seen clearly for some time. In the second quarter of 1961, imports, seasonally adjusted, were 6 per cent less than in the first quarter, and less than in any quarter of 1960.

United Kingdom exports in June were valued at £316,300,000, imports at £371,000,000 and re-exports at £13,800,000.

Shipbuilding Statistics

During the second quarter of the year orders for 42 ships of 211,000 tons gross were placed with British yards, which brings the total orders for the first half of the year to 103 ships of 342,000 tons. The comparative figures for 1960 were 85 ships of 158,000 tons and 138 ships of 353,000 tons respectively. According to a statement issued by the Shipbuilding Conference the total order book stood at 400 ships of 2,962,000 tons gross, the estimated value being £425 million. Of this total 46 ships of 518,000 tons and valued at £65,000,000 are for foreign owners. Orders placed for the twelve months ended June 30, 1961, totalled 213 ships of 615,000 tons gross, a figure which is better than for the previous three years in which the orders amounted to 574,000, 491,000 and 593,000 tons gross for 1960, 1959 and 1958 respectively.

Agricultural Engineering

Dr. P. C. J. Payne, of the Durham University Department of Agricultural Engineering, has been appointed as the first Principal of the new National College of Agricultural Engineering, and will take up his duties early next year. The college will open with a small group of students in temporary premises made available by the Ford Motor Company, at Boreham, near Chelmsford, in the autumn of 1962, pending the completion of its own premises at Silsoe, Bedfordshire, which will be ready for occupation the following year. The college will be fully residential and will accommodate between 60 and 100 students.

The main course at the college will lead to the award of a college diploma and will prepare for work in agricultural engineering at the professional level. Candidates for this course would need qualifications roughly equivalent to those needed for a degree course in engineering, or for a technical college course of similar standing. For most students this course would require three years' full-time study.

The Governors are considering how, when it is fully established, the college can best contribute to meeting the needs of students not qualified for entry to the main course. It is also intended to provide shorter courses of an advanced type for students who have already obtained a degree or the equivalent in engineering or agriculture.

A Registrar, Group Captain K. M. Crick, has also been appointed and a temporary office has been opened at Queen Anne's Chambers, 28, Broadway, London, S.W.1., (telephone, Whitehall 7010, extension 260). A prospectus will be issued in the autumn dealing more particularly with the course to be started in 1962.

Diploma in Technology

The National Council for Technological Awards has published its report for the period April, 1960, to March, 1961. It records that almost 25 per cent. of this session's first year students entered courses by virtue of their holding good Ordinary National Certificates. But for the development of courses leading to the Diploma in Technology, the Council says, few of these students would have had an opportunity of gaining a qualification equivalent in standard to a university honours degree, and many of them might never have become additions to the nation's technological man-power. During the current session 1769 students have enrolled in the first years of courses leading to the Diploma in Technology. The Council is impressed, the report states, by the growth in the number of students following sandwich courses in technologies other than engineering from 219 in November, 1957, to 1246 at the end of the year under review. Comparable figures for engineering sandwich courses are 652 and 3191. During the year covered by the report, 209 students have gained Diplomas in Technology. Nearly 5000 students are following courses leading to the Diploma of Technology, and 472 Diplomas have been awarded. Approximately 83 per cent of the engineering students and approximately 56 per cent of the students of technologies other than engineering are industry-based.

The number of courses in engineering in progress at the end of March, 1961, was 59, and the number of students enrolled 3,542, compared with 50 courses and 2763 students at the end of March, 1960. The number of courses in other technologies in progress at the end of March, 1961, was forty-one, and the number of students enrolled 1427, compared with thirty-nine courses and 1051 students at the end of March, 1960.

The Council appreciates that consideration of the type, nature and scope of courses leading to the Diploma in Technology demands much research work, the report states, and it is particularly happy that the Nuffield Foundation has found it possible to support two investigations in colleges. A grant of £15,000 for a three year project extending from April, 1959, to April, 1962, has been made by the Foundation to Brunel College of Technology to establish a small research unit to conduct social psychological research. This grant has been supplemented by Middlesex County Council to the amount of approximately £2000. The major part of the project, the report adds, is a study of the process of sandwich couse education at Brunel College. The study concentrates on the relations of college periods of study to industrial training periods. Birmingham College of Advanced Technology has recently received a grant of £6,700 from the Nuffield Foundation to support an investigation of the spacing of industrial and college training in courses for the Diploma of Technology at colleges of advanced technology.

PERSONAL AND BUSINESS

Appointments

DR. SYDNEY JONES has joined R. B. Pullin and Co., Ltd., as technical director.

MR. W. A. MATTHEWS, A.M.I.Mech.E., has been appointed chief engineer of Goodenough Pumps, Ltd.

MR. ROGER LAWSON has been appointed to the post of assistant chief engineer by Boots Pure Drug Company, Ltd.

BLAW KNOX, Ltd., announces the appointment of Mr. John C. Grist as commercial manager of the construction equipment division.

MR. F. J. EVEREST, M.I.Mech.E., has been appointed director and general manager of Stein Atkinson Vickers Hydraulics, Ltd.

HARLAND AND WOLFF, Ltd., announces that Mr. A. O. Milne, general manager of the company's repair works, has been appointed to the board.

THE PLESSEY COMPANY, Ltd., announces the appointment of Mr. A. Robert Enshaw as executive director in charge of its Government contracts department.

THE HOLMAN GROUP, of Camborne, Cornwall, has appointed Dr. H. J. Phelps as consultant to two of its companies, Maxam Power, Ltd., and Goodyear Pumps, Ltd.

WILLIAM DOXFORD AND SONS (ENGINEERS), Ltd., announces that Mr. R. C. Thompson and Mr. J. F. Butler, A.M.I.Mech.E., have been appointed directors of the company.

MR. K. R. JOHNSTON, A.M.I.E.E., has been appointed assistant superintendent, turbo-generator plant department, at the Trafford Park Works of Associated Electrical Industries (Manchester), Ltd.

MR. HARRY WEST, M.I.Mech.E., M.I.E.E., managing director of A.E.I. (Manchester), Ltd., was installed as President of the Institute of Welding for 1961-62 at the Annual General Meeting on July 13.

MR. N. R. E. BROOKE, director of Guest Keen Nettlefolds, Ltd., and G.K.N. Steel Company, Ltd., has been appointed to the local board of directors of Lysaght's Scunthorpe works (a branch of G.K.N. Steel Company, Ltd.).

DR. W. J. GIBBS, M.I.E.E., has relinquished his appointment as manager of the engineering mathematics department of Associated Electrical Industries (Rugby), Ltd., and remains as a group consultant. Mr. N. Kerruish, A.M.I.E.E., has been appointed to succeed Dr. Gibbs as manager.

MR. FRANK BRADFORD, general manager of the production products division, and Mr. FRANK SMITH, A.M.I.Mech.E., general sales manager, have been co-opted to the board of directors of Headland Engineering Developments, Ltd., a member of the Headland Group of Companies.

THE SOUTH EASTERN REGION OF THE CENTRAL ELECTRICITY GENERATING BOARD announces the appointment of Mr. E. H. Boyce, A.M.I.E.E., A.M.I.Mech.E., as station superintendent of Richborough Power Station. Mr. Boyce is Deputy Superintendent of Northfleet Power Station.

MASSEY-FERGUSON (UNITED KINGDOM), Ltd., announces that Mr. R. V. Muspratt, used equipment merchandising manager, has been appointed northern regional manager, and Mr. I. D. Birdseye, area manager, has been appointed east central regional manager. Mr. J. H. Roberts has become industrial sales manager, relinquishing his position as northern regional manager.

BRISTOL SIDDELEY has announced that the following changes are to be made. Mr. R. L. Ninnes, special director responsible for technical services, will direct the activities of the company's European headquarters in Paris, to be established in September. Mr. B. D. Blackwell, deputy chief engineer, aero research and development, is to succeed Brigadier J. Innes (a special director) as business manager, aero.

HUMPHREYS AND GLASGOW, Ltd., announces that Mr. Godfrey Davis, sales director, has been appointed assistant managing director. Mr. Roy Withers and Mr. Derek Lennon have joined the board of directors: Mr. Withers is chief engineer ; Mr. Lennon is responsible for all overseas chemical plant. Mr. Donald Yates has been appointed an associate director and head of Humphreys and Glasgow's construction department.

BLAW KNOX, Ltd., announces the appointment of Mr. Edward Goodwin as engineering manager in technical and administrative control of the Engineering Department under the general direction of Mr. J. E. Conacher, chief engineer.

MR. D. F. CAMPBELL, chairman of Davy-Ashmore, Ltd., has announced his intention to retire from the board at the conclusion of the forthcoming Annual General Meeting in September. The board of Davy-Ashmore, Ltd., has designated Mr. M. A. Fiennes to succeed Mr. Campbell as chairman, and Mr. L. H. Downs will become vice-chairman. Mr. Fiennes is group managing director of Davy-Ashmore, Ltd., and will continue in that office. While remaining chairman of Davy and United Engineering Company, Ltd., one of the principal companies in the Group, Mr. Fiennes has now relinquished his appointment as managing director of that company and Mr. M. F. Dowling has been appointed in his place. Major W. R. Brown, a director of Davy-Ashmore will also retire at the conclusion of the annual general meeting, but will remain a director of Ashmore, Benson, Pease and Co., Ltd.

Business Announcements

CHAMBERLAIN PLANT, Ltd., has opened a new depot at Scotter Road, Scunthorpe, to serve the north eastern area of the United Kingdom.

MR. PETER BROOKS, A.F.R.Ae.S., presently fleet planning manager of B.E.A., is to join the board of British Executive and General Aviation, Ltd., as deputy managing director.

THE SPOONER DRYER AND ENGINEERING COMPANY, Ltd., Ilkley, Yorkshire, has opened two new bays, having a floor area of approximately 25,000 square feet at its Moorland Engineering Works.

DICKSON AND MANN, Ltd., Armadale, West Lothian, has opened a new 15,000 square feet extension to the Bathville Steel Works to supplement the manufacturing capacity for coal-handling and bulk-handling equipment.

FORD MOTOR COMPANY, Ltd., is to introduce a new estate car based on the 105 E car and superseding the " Escort "/" Squire " ; it will be in volume production and available on the home market in September.

THE DAVID BROWN CORPORATION (SALES), Ltd., machine tool division, states that as from Monday, August 28, its works and offices will be transferred to new premises at Ashburton Road, Trafford Park, Manchester, 17 (telephone, Trafford Park 4741).

A. G. FUR INDUSTRIELLE ELEKTRONIK, Losone-Locarno, Switzerland, has appointed Matchless Machines, Ltd., 18, Bolton Street, London, W.1. (telephone, Grosvenor 2661), as its representative for the sales and service of its machines in the United Kingdom.

FERODO, Ltd., is building a new £2,500,000 factory at Griffiths Crossing, Caernarvon, for the manufacture of textile brake linings and clutch facings and non-slip stair treads. The foundation stone was officially laid on Monday, July 17, and it is expected that the factory will be in production by April, 1962.

MATERIALS HANDLING EQUIPMENT (GREAT BRITAIN), Ltd., 40a, Dover Street, London, W.1, announces that, in order to meet demand for its 'Kestrel' and 'Falcon' side operating fork lift carriers, and 'Lizard' electric reach trucks, as from August 14, production and key personnel will be transferred from Maidenhead to the larger works of the Hunslet Engine Company at Jack Lane, Leeds, 10 (telephone, Leeds 32261). The London and Maidenhead offices of M.H.E. are to be merged, and from August 21, will be located with the Hunslet Group London Offices at Locomotive House, 30-34, Buckingham Gate, London, S.W.1 (telephone, SULlivan 2875-6-7-8).

THE GENERAL ELECTRIC COMPANY, Ltd., of England, is to supply, via the Canadian General Electric Company, the radio and multiplexing equipments for a broadband radio link between Moncton in New Brunswick and Gore in Nova Scotia. The link will consist of two terminal and two repeater stations and will carry two both-way s.h.f. radio channels operating in the 6000 Mc/s frequency band, forming part of the Canadian East Coast microwave network being developed by the New Brunswick Telephone Company and the Maritime Telegraph and Telephone company. The equipment will convey either a television circuit or 960 speech circuits on each radio channel, and will link up with other G.E.C. equipments in the network operating in the 2000 Mc/s band.

HILGER AND WATTS, Ltd., 98, St. Pancras Way, Camden Road, London, N.W.1, announces that it has acquired the whole of the issued share capital of Microwave Instruments, Ltd., North Shields, Northumberland. Mr. J. Bilbrough, will continue to be managing director of Microwave Instruments, Ltd.

Contracts

CANADIAN PACIFIC STEAMSHIPS, Ltd., has placed an order with the Burntisland Shipbuilding Company, Ltd., for a 6000-ton deadweight motor cargo liner.

W. H. ALLEN, SONS AND CO., Ltd., has received the order from the Shaw Savill Line to supply eight 450kW generators for the company's four new cargo ships.

THE UNION CASTLE LINE has placed an order with the Decca Navigator Company, Ltd., to supply ten ships of the Union Castle fleet with the Arkas automatic pilot.

BLAW KNOX CHEMICAL ENGINEERING COMPANY, Ltd., has been awarded a contract by J. Bibby and Sons, Ltd., to furnish a plant at Liverpool for the solvent extraction of soya beans and other oilseeds.

THE GENERAL ELECTRIC COMPANY, Ltd., has received an order from William Hamilton and Co., Ltd., to supply a 2000 tons per hour materials handling plant to be installed in a self-unloading ship.

BRISTOL AIRCRAFT, Ltd., is expecting an order totalling £25,000,000 to £30,000,000 for a " Bloodhound " Mk. II system from Switzerland. This would be the largest export order ever placed for British guided weapons.

ALEXANDER STEPHEN AND SONS, Ltd., announces that it has received from Thomas and Jno. Brocklebank, Ltd., an order for two 10,000-ton deadweight cargo ships having a speed of 16½ knots and each powered by a Mk. 7RD. 76 Sulzer diesel engine.

HUNTING AIRCRAFT, Ltd., a company of the British Aircraft Corporation, has received an order for a number of " Jet Provost " trainers for the Sudan Air Force ; the aircraft will be fitted with machine guns and provision for rockets and bombs.

JOHN WIGHT AND CO. (EDINBURGH), Ltd., is the successful contractor for the second stage of the Ayr-Prestwick by-pass. The Secretary of State for Scotland has authorised the commencement of work on this stage (stage I was opened in March of this year) along a new route lying to the east of Ayr approximately 1½ miles long. The work will be supervised by Ayr County Council as the Secretary of State's agents. It is estimated to cost £255,000 and is expected to be completed in about eighteen months.

JOHN THOMPSON (WOLVERHAMPTON), Ltd., has been awarded the contract by the industrial Estates Management Corporation for Wales, to supply the steam-raising plant to provide steam for industrial space heating and process work for thirty-four factories on the Treforest Industrial Estate, Pontypridd, South Wales. The boiler plant will consist of eight oil-fired Super-Economic shell boilers with superheaters to meet a demand of 180,000 lb of steam per hour at 250 lb per square inch and 600 deg. Fah.

Miscellaneous

MEASURING QUANTITY IN CHEMICAL PRODUCTION.—The Department of Scientific and Industrial Research has published a booklet with the title " Quantity Measurement in the Chemical Factory " which stresses the importance of applying scientific method to problems of maintaining product quality. Both simple and complex techniques of analysis are examined and some methods in current use are described and illustrated.

DUAL-OUTPUT HYDRAULIC SERVO.—It will be recalled that Bedford vehicles of the " TK " series (September 9, 1960, page 437) have a servo assisted hydraulic brake system of which the distinctive features are independent hydraulic circuits for front and rear brakes, and the use of a purely mechanical linkage from the pedal to the servo and master cylinder unit. This servo, which is called " pull-type," since it is worked by a tie-rod in the manner usual for vehicles with mechanical brakes, is of suspended vacuum design so that the exaggerated volume at the low-pressure end of the cylinder acts as the reservoir. A detailed description, together with servicing, diagnosis, and workshop instructions, are included in a brochure now available from Clayton Dewandre, Lincoln.

CONTINENTAL AFFAIRS

by Our Continental Editor

Austrian Oil Production

In the thirty years which have passed since the first oil was found in the Vienna region, the Austrian oil industry has assumed substantial proportions with an annual output of about 2·7 million tonnes, to which must be added some 800 million cubic metres of natural gas. Although the amount of oil does not fill the domestic demand, so that the need for substantial imports remains, the Austrian oil industry is nevertheless of considerable importance. The present article surveys the production and refining of oil in Austria and describes the installations of the new refinery at Schwechat which is approaching completion.

ABOUT 95 per cent of the Austrian production of crude petroleum and 99 per cent of natural gas is carried out by the Österreichische Mineralöverwaltung Aktiengesellschaft, ÖMV-AG) Austrian Petroleum Administration, Ltd.) whose share capital is owned by the Austrian State.

The ÖMV-AG is a young undertaking, although the oil industry in Austria goes back nearly a century to when the deposits of Galicia, then an Austrian province, were first commercially exploited and a considerable industry was built up. In the Vienna Basin, the first oil finds were made in 1930, and four years later the first really productive exploratory drilling was made. This aroused the interest of foreign oil companies, and a number of new companies were set up by foreign groups. As far as German property was involved this was taken over at the end of the war by the Soviet occupation authorities. On the basis of the Austrian State Treaty, these enterprises were transferred on August 13, 1955, to the Austrian State against a payment to the Soviet Union of 10 million tonnes of crude oil in equal annual instalments. These deliveries were eased from 1959 onwards by the Soviet Union supplying Austria free of charge with an annual quantity of 500,000 tonnes of Soviet petroleum.

Most of the transferred enterprises were grouped together in the ÖMV-AG. They comprise Aderklaa, Auersthal, Matzen, Mühlberg, and Neusiedl, and (since July 1, 1959) also the Erdölproduktions G.m.b.H. Production of natural gas is considerable, and is constantly being increased by pipeline extensions. This table shows the production during 1958.

Enterprises	Crude oil (tonnes)	Wet gas (1,000,000 cubic metres at s.t.p.)	Dry gas (1,000,000 cubic metres at s.t.p.)
Aderklaa	61,124	9·94	—
Auersthal*	886,600	69·66	—
Matzen*	1,421,035	225·40	80·73
Mühlberg	190,077	28·53	26·21
Neusiedl	100,778	4·48	—
Erdölproduktions G.m.b.H.	32,529	—	—
Fischamend	—	—	0·53
Zwerndorf	—	—	361·18
Total	2,692,143	338·01	468·65

The output is processed at refineries at Korneuburg (annual throughput 350,000 tonnes crude) Schwechat (700,000 tonnes per annum), Moosbierbaum (360,000 tonnes), and Lobau (rented) (400,000 tonnes), giving a total annual capacity of 1·81 million tonnes per annum, to which must be added the expansion at Schwechat which came on stream last year and when fully completed will add a further 1·6 million tonnes per annum.

In accordance with the "Vienna Memorandum" signed in conjunction with the 1955 State Treaty, Lobau Refinery was handed back to Shell-Vacuum Oil Company in June, 1958. For the time being it continues to be operated by ÖMV under a rent agreement.

Between taking over from the Russian administration and the end of 1958, investments totalled 2000 million Austrian schillings (approximately £28,000,000). These investments covered modifications to comply with Austrian legal requirements, nationalisation measures, new vehicles and machinery, and a number of important installations, in particular a central compressor station for natural gas at Auersthal with a daily capacity of 1,000,000 cubic metres, a pipe bridge across the Danube at Mannswörth, a feeder centre at Baumgarten, a central workshop at Gerasdorfer Strasse and headquarters for the Southern Region Field Administration at Gänserndorf, as well as over 200km of roads.

Further districts were prospected in 1957 using seismic, gravimetric, magnetic, radiometric, and also telluric methods (measurements of ground currents).

Schwechat Refinery

One of the largest projects is the expansion of the Schwechat refinery, which was begun in April, 1958. As a first step the bitumen plant was completed. Our illustration (Fig. 1) shows a more advanced stage, with some parts of the fractionating plant, the power house and the buffer storage tank farm, nearing completion.

The new ÖMV refinery at Schwechat is intended to supply the Austrian market with a number of petroleum products which the other refineries, which are technically obsolescent, cannot supply at all or not in sufficient quantity. In addition to an increase in capacity there will also be a saving in transport costs of about 35,000,000 Austrian schillings annually, and a decrease in heat consumption will save another 25,000,000 schillings. Increased profits will result also from the use of the refinery gases for petrochemical and other purposes. The planned capacity of 1·6 million tonnes per annum corresponds roughly to the combined capacity of the old refineries and also to the output rate in the current decade from the country's own present oilfields if compensation deliveries to the U.S.S.R. are deducted.

Although the Schwechat refinery in this manner substantially contributes to Austria's production capacity, this does in no wise imply that domestic production is likely to make the country independent of foreign supplies. Since 1937 consumption has grown far above the world average, and the share of oil in the total consumption of energy rose from 8 per cent to nearly twice that figure. The consumption of oil products is likely to double by 1965, and large-scale imports will remain essential.

As regards economy in transport costs, it is a great advantage that within 200km of the refinery are 75 per cent of the Austrian petrol consumption, 85 per cent of the consumption of fuel oil, and about 80 per cent of the consumption of gas oil.

Schwechat is being equipped with a low-pressure distillation plant, a catalytic reformer, a gas liquefaction plant, and a bitumen plant, as well as an ethylene recovery plant. There will also be a catalytic cracking plant which it is planned to complete with a vacuum distillation plant.

In the reforming plant highest grade petrol with an octane number of 100 will be produced, and the catalytic cracking plant will substantially increase the total output of petrol. Planning of the refinery was carried out by Lurgi G.m.b.H., Frankfurt/Main.

Atmospheric Distillation Plant.—The atmospheric distillation plant (Fig. 3) forms the core of the refinery. Here the three grades of

Fig. 1—Schwechat refinery in course of construction (June, 1960)

CONTINENTAL AFFAIRS *(Continued)*

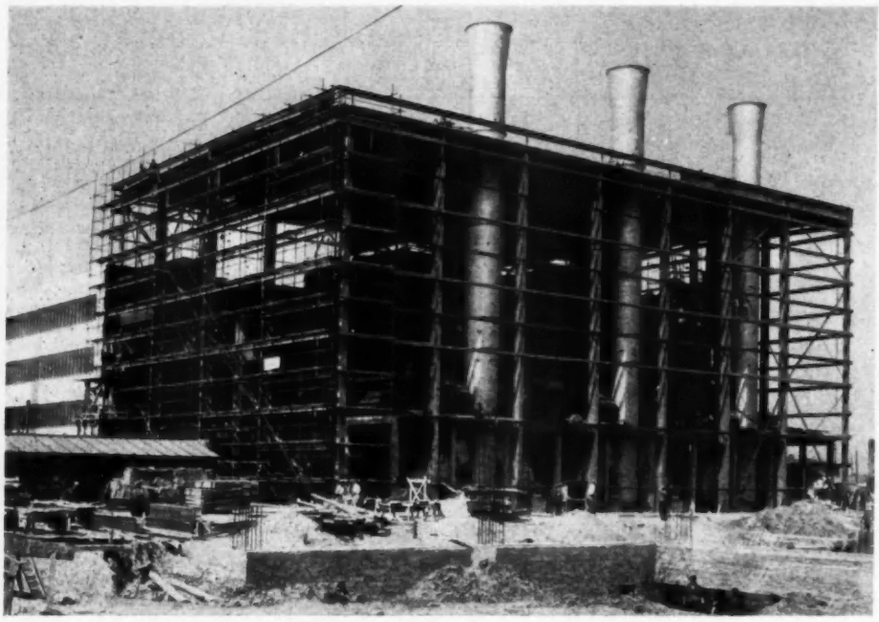


Fig. 2—Power-house under construction (April, 1960). The boilers are being erected

crude (two Austrian and one Russian (which the refinery receives are fractionated into the following products: light petrol, light naphtha, heavy naphtha, kerosene, gas oil, top spindle oil, and fuel oil.

After heating in a pipe still furnace the crude oil is fractionated in a column into a total petrol fraction, kerosene, gas oil, top spindle oil and fuel oil. This installation is designed to cope with large fluctuations in the proportions of these components, depending upon the kind of crude which is used. After intermediate storage the total petrol fraction is further split into light petrol, and light and heavy naphtha. Kerosene and gas oil made from Matzen crude are treated with alkali in order to remove naphthenic acid which is subsequently recovered. Light petrol, kerosene and gas oil are pumped by way of buffer storage to the Lobau tank farm. Top spindle oil and fuel oil are pumped to the fuel oil tanks.

The throughput is 5000 tonnes daily, or approximately 1·6 million tons per annum.

Gas After-Treatment.—Refinery gases from atmospheric distillation, unifier-platformer and cracking plants contain nitrogen, hydrogen and a range of carbo-hydrates from methane to top vapour. This mixture is treated in order to condense the top vapour liquid gas, propane and butane. The remainder, mainly gases lighter than propane, are used in the refinery for heating purposes. Light petrol is returned to the atmospheric distillation plant, propane and butane are transferred to the liquid gas storage.

Hydrogen sulphide, which is one of the components of the input mixture, is removed in a DEA plant. Throughput of the gas treatment plant is 30 tonnes per hour.

Unifier-Platformer.—This section which has a capacity of 7000 barrels per day (250,000 tonnes per annum) serves to turn low-octane light and heavy naptha from the atmospheric distillation plant into a high-octane platformed product.

In the unifier the input gas is cleansed of hydrogen sulphide and contaminants by reacting it with hydrogen at 360 deg. Cent. at a pressure of 60 atmospheres in the presence of a cobalt-molybdenum catalyst.

This gas is then heated in the platformer to about 530 deg. Cent. in three reaction vessels in the presence of a platinum catalyst and hydrogen. The product is a platformed gas with an unleaded octane number of 97. It is stabilised and pumped by way of buffer storage into the Lobau tanks.

Bitumen Plant.—At the time of its construction the bitumen plant was particularly urgent because of the shut-down of the bitumen sections at Vösendorf Refinery and the increasing demands of the road programme.

The new bitumen plant is laid out for the processing of 400 tonnes per day of basic napththa tops from Matzen crude oil. Its daily output amounts to 150 tonnes of soft bitumen or a correspondingly smaller quantity of hard bitumen, which are produced by vacuum distillation, also a heavy fraction which is further processed partly into lubricating oils and partly with fuel oil. Soft and medium bitumen are used in road construction while the hard grades are employed in the building and other industries. Whereas usually hard bitumen is produced by an oxydation process, the Schwechat plant employs a pure distillation process which yields product qualities which are advantageous for certain purposes, e.g. the manufacture of emulsions.

The installation comprises tanks for the raw material (tops residue), two vacuum distillation plants arranged in parallel, each consisting of one pipe still furnace, followed by a vacuum fractionating column, and the tanks and mixing equipment for the finished products, tanks for storing by-products, and equipment for dispatch in road and rail tankers, drums, and in block form. An oxydation plant is being added.

The top residue is continuously heated to 420 deg. Cent. and its vapour and liquid components are separated in the fractionating column. For producing particularly hard bitumen, both furnaces and columns can be put in series. Distillation under vacuum is necessary for maintaining a high quality in spite of the elevated temperature to which the bitumen is subjected. Special steps have to be taken to cool such components as the stuffing boxes of the pumps, and to provide special expansion joints in the pipework.

The installation is almost fully automated and all controls and instruments are located in a special control room. The first stage of the plant (which did not include the oxydation plant) cost approximately 16·5 million Austrian schillings. Principal quantities are shown below:

Steel weights:	
Seven tanks	215 tonnes
Two furnaces and one preheater	72 tonnes
Fractionating columns ... ... (associated equipment, steel structures, pipe supports and bridges, &c.)	170 tonnes
Pipes	152 tonnes
Total length of pipework	8km
Insulated pipework (glass fibre) ...	400m
Insulated pipework (glass fibre and heated)	450m
Multiple copper tubing for pneumatic instrumentation	over 1000m
Valves (various sizes)...	640
Steel compensators	Fifty-five
Separators	Twenty-four

Tanks and Transport Installations.—Crude petroleum of three different origins—Matzen crude, Austrian P-crude, and Russian import crude—are piped from the Lobau control tank farm to the refinery, where storage for these grades consists of eight tanks (totalling 134,000 cubic metres. The tanks (built by Vöest) are fitted with floating roofs (Wiggins design) so as to reduce evaporation losses and achieve a high degree of safety. For a number of products buffer storage tanks are provided which for the

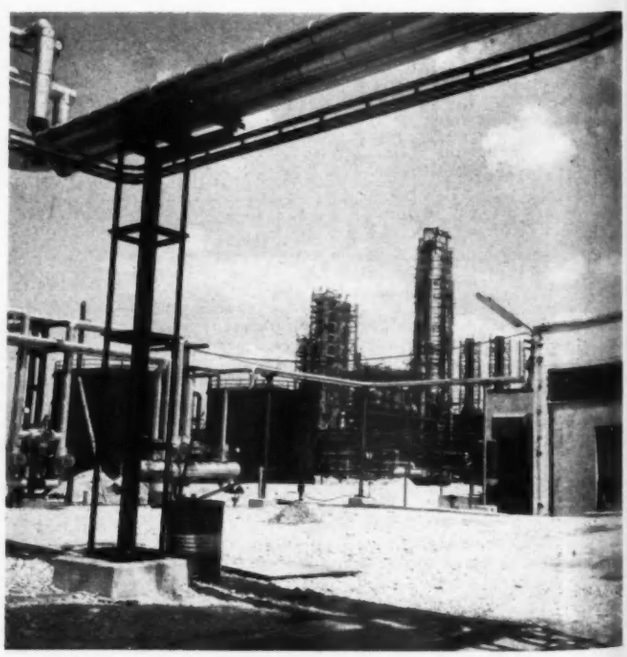


Fig. 3—Distillation plant with main fractionating column

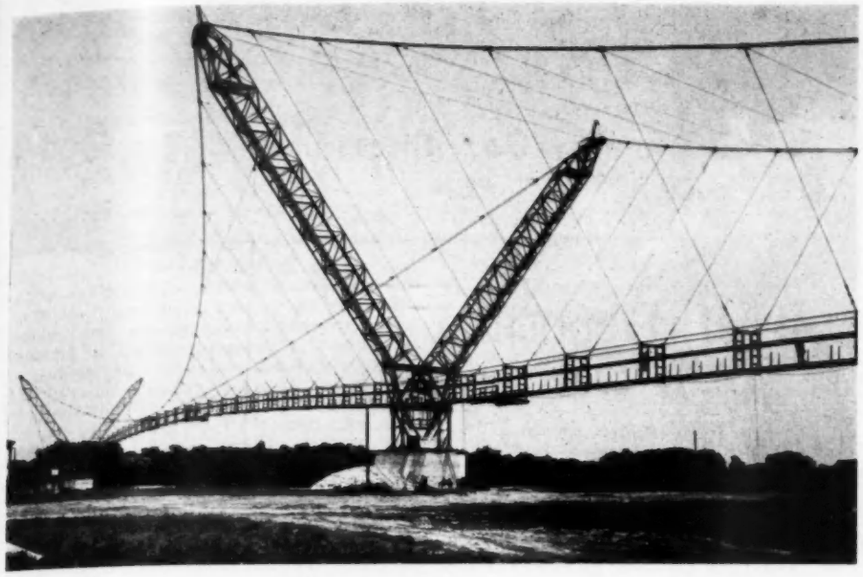


Fig. 4—Second pipeline bridge across the Danube. It connects the new Schwechat refinery with the central tank farm in the Lobau on the left bank

most part are situated in the area of the atmospheric distillation plant where there is also the pumping station serving the Lobau pipelines.

A tank farm in the refinery serves the storage of liquefied gas, top spindle oil and residues from atmospheric distillation.

For liquefied gas are provided horizontal storage cylinders totalling about 2000 cubic metres, for butane there are spherical holders with a total capacity of about 3500 cubic metres. Fuel oil is stored in tanks ranging from 5000 to 40,000 cubic metres and totalling 195,000 cubic metres. Means for loading liquefied gas are sited next to the liquefied gas store. For fuel oil loading facilities are being provided, for road and rail tankers near the fuel oil tank farm, and for tanker vessels at the Lobau control tank farm. This loading point is directly supplied from the refinery.

Pipe System.—Drains, water mains, including cooling water, and the high-pressure natural gas main are buried, the remainder, including product pipes, steam pipes, &c., are above ground. Connections with the old Schwechat refinery are provided.

The underground pipes are up to 1·2m in diameter, those above ground up to 600mm diameter. Total length of pipes between the various sections of the plant, and the plant and the Lobau storage farm, is about 150km (without heating).

Waste water from the refinery is conducted through a common drainage system to an oil separator and from there through a 600mm diameter pipe to the Danube.

Above-ground piping is laid in trenches parallel to the refinery roads.

Safety Installations.—The refinery possesses a blow-down system which collects the gas blown off by the safety valves, recovers the liquid components and passes the gases to the 56m-high flare which can burn up to 40,000 cubic metres per hour.

A system of five hydrants covers the area. Each hydrant is supplied from two sides, the pipes being laid underground. The pumping plant is housed in the power station. In addition to plain hydrants along the roads there are hydrants fitted with jets installed in the various sections which can alternatively be used as foam throwers. Fire brigade headquarters are situated in a central building and can immediately be reached from a large number of fire alarms.

Thermal Power Station.—The refinery is supplied with steam by two networks, one working at 4 atmospheres and the other at 12 atmospheres (gauge). Electricity is supplied at 6kV, 500V and 220V, compressed air is available for power and for instrumentation, and there is some supply of fresh water and of re-circulated cooling water, fuel gas, and sodium hydroxide solutions of various concentrations, as well as hydrochloric acid. All these services are centrally furnished from the thermal power plant.

The boiler house (Fig. 2) contains three high-duty radiation boilers, two with a maximum capacity of 92·5 tonnes per hour, and one with a maximum capacity of 76 tonnes per hour. One of these is always kept as a standby. The boilers are fitted with combined gas and fuel-oil burners.

Steam at 80 atmospheres gauge drives three turbo sets with an output of 8·5MW each. The turbines are three-cylinder twin-exhaust condensing turbines. As a standby an independent gas turbine plant of 6·5MW is provided which can burn either natural gas or heavy diesel fuel. Additionally there is a 20kV substation which connects the refinery to the Vienna municipal electricity system. The various main sections of the refinery are supplied with current at 6kV. Large installations use this voltage, smaller ones are supplied at 500V from substations. Lighting is connected to a separate system. The whole installation operates largely automatically.

Compressed Air.—Three two-stage screw compressors are provided with a maximum output of 2770 cubic metres of free air per hour, at a delivery pressure of 8 atmospheres. A continuously-operating plant with a capacity of 6000 cubic metres per hour dries the air before it is supplied to the power and instrument mains.

Water.—Supplies for technical purposes come from five wells. Some of the well water is used directly, the major part, about 800 cubic metres per hour, side -carbonised in four lines each with a capacity of 200 cubic metres per hour Boiler feed is fully demineralised by an ion-exchange plant. A ventilated cooling tower with nine cells for 7500 cubic metres per hour cools the water which is then re-circulated.

Gas.—Natural gas for the refinery and the power station is supplied by high-pressure main from Zwerndorf, and reduced and mixed with refinery residual gases as required.

Chemicals.—Alkalis and acids which are used for regenerating the ion exchangers of the water preparation plant, and in the refinery sections, are stored near the power station and there diluted as required.

Pipe Bridge.—The new pipe bridge (Fig. 4) at river kilometre 1917·7—the second of its kind after the one at nearby Mannswörth (Barbara Bridge)—connects the refinery on the right bank with the control tank farm at the Lobau on the left. Like the Barbara Bridge it is a suspension bridge with inclined cables. One of the vee-towers is founded on a sandbank near the river bank, in order to reduce the central span to 260m (Barbara Bridge 320m). The side spans —also suspended—are each 115m long and their outer ends abut on the cable anchorages.

The suspension consists of 6mm-thick wire ropes which are laid across the river by large flat-bottomed barges, hoisted up to the towers by cranes and tightened by hydraulic presses. The bridge will eventually carry thirteen pipes of various sizes (as compared with one natural gas main on the Barbara Bridge). There are three crude oil lines, one kerosene line, two gas-oil and three petrol lines, to which later will be added a natural gas main, a fuel oil main and a pipe for heating the others.

The pipes are suspended every 8·4m in sliding stirrups and are accessible from a catwalk. The towers have a height of 37m, and the minimum clearance above the shipping channel is 8·5m at the highest navigable water level. The bridge, like its predecessor, was built by Waagner-Biró AG, Vienna-Graz, which originated this design.

Eurochemic Plant at Mol

Agreement has been reached on the main specifications for the "Eurochemic" European processing plant for nuclear fuel at Mol, Belgium. The Board have authorised the management to begin construction on the basis of a pre-project developed in collaboration with Saint-Gobrain Nucléaire from the original plans prepared by the Eurochemic Study and Research office.

The plant will have two principal objectives, i.e. the experimental investigation of processing problems likely to arise on an industrial scale within the next ten to fifteen years, and in the meantime to reprocess fuel from European reactors. The capacity for this work is to be 350 kg per day for natural uranium elements, or 200 kg to 250 kg per day for elements enriched up to 5 per cent. Studies have been initiated regarding the reprocessing of fuel of higher degrees of enrichment at a later stage. In order to gain the maximum experience, the plant has been designed to accept a wide range of fuels (uranium metal, alloys, oxide) and canning materials (aluminium, magnesium, zirconium, Zircaloy, stainless steel). The company will also have its own research laboratories.

Construction of the plant will be carried out with the collaboration of architect-engineers from the countries participating in the company, namely Saint-Gobain Nucléaire (France); Nohab (Sweden); Belchim (Belgium); Montecatini (Italy); Argtu (Germany); Comprimo (Netherlands); and Noratom (Norway).

Site development at Mol is already in progress, and it is planned to start construction in the late autumn and to have the plant ready for operation in the second half of 1963. Specifications of the plant will be in conformity with relevant international safety norms. In addition to what has already been mentioned, there will be provided substantial reception and storage space sufficient for 80 tons of irradiated fuel. There will be no mechanical decanning; mechanical handling will be limited to the cutting of head and end pieces. Chemical decanning will be effected in dissolvers, one for fuel elements of up to 1·6 per cent enrichment, another for fuel elements of higher enrichment. A first combined decontamination and partition cycle by T.B.P. extraction in pulsed columns is to be installed, as well as a second cycle for uranium purification, and a final purification, stage by silica gel.

Direct maintenance is foreseen in the active parts of the plant; the equipment corresponding to the different parts of the process will be distributed in a sufficient number of cells to permit partial decontamination. Finished products will be stored in a separate building, with different areas for natural uranium, enriched uranium and plutonium.

Correction

In our issue for May 26, page 881, we referred to a method of floor construction exhibited at the recent German Industries Fair at Hanover by Thyssen Industrie G.m.b.H., Dinslaken. The article implied that the flooring shown was produced by Thyssen whereas this firm only supplied the galvanised wide steel strip used in its manufacture. The maker in fact was Robertson Bauelemente G.m.b.H., an associated company of Robertson Thain, Ltd., Ellesmere Port, Cheshire.

THE AMERICAN SCENE

By Our American Editor

Automatic Production of Deposited Carbon Resistors in North Carolina

A wholly new concept in the automatic manufacture of electronic components, combining statistical quality control with fully mechanised processing—all under the guidance of a digital computer—is now being applied at the North Carolina Works of the Western Electric Company. A number of inter-connected robots manufacture deposited carbon resistors, which must meet severe electrical requirements, yet operate thousands of years on the average without failure. So great is the reliability demanded of the product that manual techniques of manufacture are impractical. The resistors are used in immense quantities and in a variety of electronic equipment including radar and missile control systems.

AN automatic production line, completely computer-controlled, for making deposited carbon resistors recently went into operation at the North Carolina Works of the Western Electric Company at Winston-Salem. The line (Fig. 1) consists of eleven stations which are all tied into a central control by a general-purpose computer. The feedback of process data from three key points along the line permits rapid closed-loop operation. The process begins with the deposition of carbon on a small ceramic core. Then the core (Fig. 2) goes successively through inspection, termination, capping, spiralling to value, second inspection, moulding of a protective case, marking, leak inspection, final inspection and packing—with the resistor remaining untouched by hand. Western Electric decided to develop the automatic line when an early survey indicated a considerable increase in total resistor usage, with a definite trend toward the deposited carbon type, and a severe need for greater reliability in resistors, particularly for military usage.

Control Equipment

The heart of the control equipment is a digital computer (Fig. 3) with a 4096-word magnetic drum memory. It was redesigned extensively with the addition of input and output circuits required for it to control the programming, set-up and feedback control of individual machines. Basically, the computer performs in three areas: (1) It programmes production control. A month's production requirements can be fed into it at random. It completely schedules and programmes the work, arranging it according to the four resistor power sizes and an almost infinite number of possible resistance values. (2) Using the methods of statistical quality control, it analyses control data plotted at three critical points in the automatic process and applies statistical tests to determine if a trend is developing. (3) It formulates the information to detect any drift away from the accepted manufacturing tolerances. No control action takes place while this analysis indicates normal statistical distribution around a desired nominal. But when a trend away from this condition develops, the computer uses stored data to calculate new set-up information for the appropriate station.

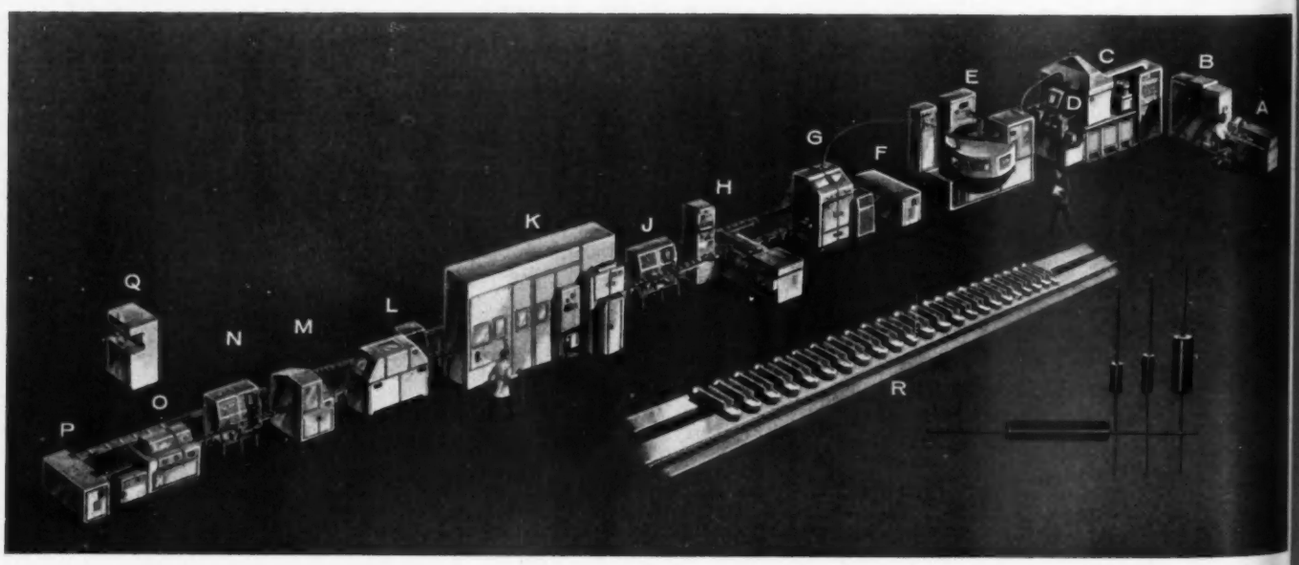
In addition to feedback control functions, the computer provides an initial set-up of rating size at eight machines and resistance value at six machines. Time sharing of the input equipment and of portions of the output equipment helps to conserve apparatus in the computer system. The computer output is stored in transistorised registers, with such set-rating as size, gas flow, and core speed requiring binary registers for each machine. Those machines requiring decimal set-up—the helixing machine, the marking machine and the two inspection storage bridges—share a single binary coded decimal register. The input unit is an analog-to-digital convertor. Although it is time-shared between the individual input stations, the 140,000 bit-per-second speed at which it sweeps data into the computer precludes any delay in the computer operation.

Coating Machine

The large batch coating method commonly used in industry proved unsuitable for the automatic deposition of carbon film. Effective feed-back control required a continuous unit-by-unit, feed-through process.

The small ceramic core is the nucleus of the resistor. It begins its long travel through the line at the coating machine where a control device regulates its speed through the three separate chambers of a horizontal furnace. A horizontal, three-roller support system rotates it to ensure uniformity of coating. To avoid oxygen contamination, inert nitrogen gas is continually flushed through the deposition area of each chamber, forming a pressure-seal against the end-baffles. In the heating areas of each chamber, a temperature of over 2000 deg. Fah. decomposes methane gas to form crystalline carbon on the core. The core is then cooled to room temperature and sent to an inspection station.

Three parameters govern the resistance coating value: the speed of the core through the coating zone, the pyrolysis temperature and the flow of methane gas. The computer controls these parameters through a feedback loop around the furnace. It computes the control



A—Computer.
B—Output-input control station.
C—Coating station.
D—First inspection station.
E—Terminating station.
F—Conveyor control equipment.
G—Capping station.
H—Helixing station.
J—Second inspection station.
K—Encapsulating station.
L—Leak detector station.
M—Marking station.
N—Third inspection station.
O—Packing station.
P—Conveyor control equipment.
Q—Cap-lead welding machine.
R—Detail of conveyor line.

Fig. 1—Automatic production line for the manufacture of deposited carbon resistors

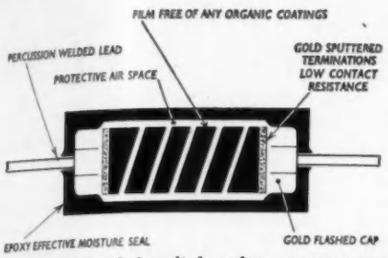

FILM FREE OF ANY ORGANIC COATINGS
PERCUSSION WELDED LEAD
PROTECTIVE AIR SPACE
GOLD SPUTTERED TERMINATIONS LOW CONTACT RESISTANCE
EPOXY EFFECTIVE MOISTURE SEAL
GOLD FLASHED CAP

Fig. 2—Design of deposited carbon, epoxy encapsulated resistor made on automatic production line

Fig. 4—Terminating machine having thirty-six rotary indexing stations with vacuum chambers for gold contact sputtering

information from statistical quality control data stored on the memory drum. Solenoid-actuated digital flow valves provide the computer with the precise binary unit response needed to control the gas flow in the coating zone.

First Inspection

The first inspection station forms a feedback loop from the coating furnace through the computer. Here, the coated core goes between four probes using the Kelvin bridge principle. Analog voltage proportional to resistance is "digitised" and fed to the computer memory drums where it is stored and sampled on an AQC basis against that of the programmed requirements also stored on the drum. The results from this inspection form the basis for feedback control of the furnace. A graph at this station records the test for visual monitoring. This station also inserts magnetic slugs as instructed by the computer to separate individual lots of resistors when changes of resistance value or of resistor size are called for.

Terminating Machine

The carbon-coated core next goes to a terminating machine (Fig. 4) which sputters a gold contact over each end. Rotary indexing vacuum chambers are the basic tools of this machine. A few of the thirty-six stations are used to load and unload parts. The others are used for pump-down, back-filling of argon gas and for the sputtering, as the vacuum chambers advance on their circular track.

The core first goes to a pick-up station to be fitted with a mask, which holds and protects the centre of the core. Since there are four different sizes of resistors, the computer programmes the proper mask sizes. The mask is loaded on to a vacuum station and covered with a bell jar, which is pumped to a vacuum and then back-filled with argon gas at low pressure. Subsequently, the ends of the core protruding from the mask are sputtered with particles from a gold cathode. The sputtering lasts for almost a minute, depositing a layer of gold approximately ten millionths of an inch thick. The gold is deposited uniformly because two rollers, actuated by an external magnet, rotate the core inside the mask to obtain maximum exposure.

Fig. 3—Digital computer with special input and output circuits for the control of the manufacturing line

Capping Machine

The ceramic core is now a resistor, and the capping machine attaches wire leads to it. The wire leads are first attached to small hexagonal caps of gold-plated brass. This is done by an automatic percussion welding machine outside the line. The cap-lead assemblies are then inserted into the capping machine which feeds them into capping chucks. The resistor core, coming from the terminating machine, is loaded on to a turret which holds it in position while the capping chucks simultaneously press the cap-lead assemblies over both ends. The machine operates on a demand basis so that the arrival of a carbon-coated core automatically triggers a capping operation. The capping force is sufficient to weld the gold plating of the cap to the gold on the ends of the core. It also creates a highly reliable, low-noise contact.

The capping machine uses two different capping assembly heads and three different sizes of caps to take care of the four resistor wattage sizes. The computer controls both the switching of the assembly heads and the changing of the cap sizes.

An automatic machine outside the line percussion-welds a solder-coated lead to the gold-flashed brass cap used in the capping operation. The weld is made at the joint of the cap and the lead by an extremely short arc of high intensity. This machine output rate is approximately 3600 parts per hour. It has changeable tooling to accommodate three different cap sizes and two wire sizes. Fail-safe devices shut off the machine or reject the part in the event that no cap is fed, a lead is not attached, or a poor weld occurs.

Helixing Machine

The helixing machine cuts a spiralled groove along the carbon film of the core to obtain the desired resistance value precisely. A computer-controlled bridge monitors the cutting, which is done by rotating the properly chucked resistor against a diamond-impregnated wheel. The servo-controls of the bridge balance when the desired resistance is reached, disengaging the bridge lathe. During cutting, the bridge also senses any non-linearity indicative of chipping or thin spots in the coating; such cores are automatically rejected. The control circuits also reject any resistor that reaches value before 75 per cent of its length is used, or fails to reach value in its full available length.

The helixing or spiralling is done "dry" and continues until the final resistor value is reached—an achievement which eliminates the hand-rubbing final adjustment method previously used. The helix lathe bridge is slightly biassed to compensate for machine inertia and for resistance change caused by the heat generated in grinding. This data is programmed and stored in the computer memory drum. The computer also ties into a servo unit that controls the speed and pitch used for proper spiralling. The spiralling time of only three seconds is a fraction of that commonly used elsewhere and was obtained by carefully balancing the rotating mechanism and using a magnetic counter-weight to hold the movable chuck assemblies against the diamond cutting wheel.

Second Inspection

The feed-back control and self-correction of the helix lathe bridge is based on a statistical quality control analysis of values inspected at the second inspection station (Fig. 5). A Wheatstone bridge, set to the desired nominal resistance value of each resistor lot by the

Fig. 5—Automatic inspection station following the helixing machine, employing computer-controlled analysis of the inspected values

THE AMERICAN SCENE *(Continued)*

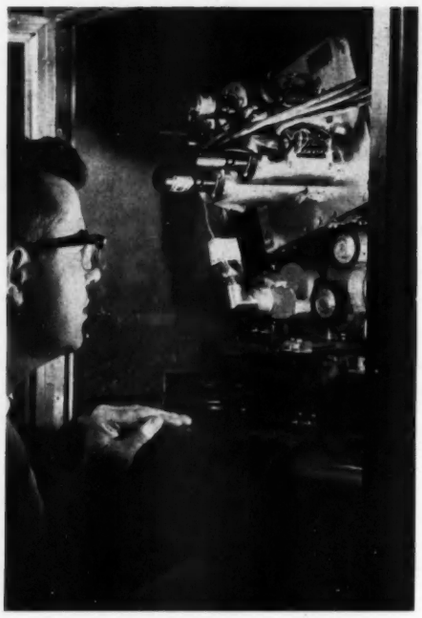


Fig 6—Offset print marking machine with planetary gear mounting of blanket roll and inking rolls

computer, precisely measures the resistance of the resistor. Off-balance voltage is "digitised" and fed back to the computer, which then determines the desired correction and corrects the helixing machine setting. Defective resistors are automatically rejected, and visual monitoring of values is provided at this station.

Encapsulating Machine

The resistor next feeds into an encapsulating machine. Here, a pre-cured epoxy shell is fitted over the core, and two partially cured epoxy pellets are inserted over each lead. Held between resilient rubber chucks, the resistor moves through an oven for approximately fifteen minutes in a curing temperature of over 300 deg. Fah. The resilient chucks prevent escaping trapped air from causing leaks in the finished resistor. The shell, now fully cured, does not melt, and rests on the gold caps of the resistor, retaining an air space along the resistor body to prevent organic contamination of the carbon film. The partially cured pellets on the leads do soften, forming an effective seal with the shell. The resistors then pass through cooling water jets which terminate the cure of the epoxy pellets. Detection circuits within the machine reject any resistors with missing shells or missing pellets.

Leak Detection

Moving along a conveyor from the oven, the resistor is picked up by the holding clip of a leak inspection turret. The holding clip immerses it in a hot water bath containing a wetting agent to prevent surface bubbles from clinging to the resistor body. The heat expands the air inside the capsule, and a series of ten photo-electric cells watch for air bubbles which would indicate a leak. A special memory device rejects improperly sealed resistors as they leave the tank. The heart of this device is a mechanical memory tab associated with each resistor holding clip. The tab retains the identity of any individual resistor rejected at any one of the leak detectors. The machine can detect leaks as small as 2×10^{-6} cubic centimetres per second.

Marking Machine

A computer-controlled marking machine (Fig. 6) now stamps the rating, resistance value, production lot number and date on the encapsulated resistor. The machine uses a modified offset printing technique. Conventional offset printing requires a small type head which reciprocates during the inking cycle of the blanket roll. In this machine, however, the necessity for response to computer control dictated the use of a rather bulky typehead. Therefore, it was decided to mount the blanket roll and inking rolls on a planetary gear arrangement. This permits the type head to remain stationary, and permits the addition of servo drives to make automatic type changing feasible.

Servo drives controlled by the computer can set any one of forty-five different code numbers with over a 1,500,000 permutations of code and resistance value combinations. The automatic controls also provide blanket roll cleaning between code changes and during idle periods which might otherwise allow the ink impressions to dry on the blanket roll.

The final inspection station is a feed-back control point and resets the preceding inspection station to compensate for shifts in resistance value caused by the heat of encapsulation.

Conveyor Systems

Between the first four stations of the automated line, the resistor core is transported by being blown through a plastic tube with gentle air pressure. From the capping machine through the succeeding operations, the resistor moves from machine to machine by a conveyor control system. This system uses individual stainless steel pallets which move along continuously-running conveyor belts. The pallets transport individual resistors to the machine operating position and receive the resistor after the completion of operation. The conveyors are part of each individual machine and provide an indexing pallet transport mechanism. A rubber-tipped push rod retains the resistor on its tip by means of a vacuum system connected through the hollow rod core. A suitable cam actuating mechanism for the push rod is synchronised with the machine operation, loading the resistor into the machine. Space is allowed between each machine for the accumulation of a five minute "bank stock," and each machine feeds from this storage space on a demand basis. Inventory control is maintained, since each machine shuts off when the storage space fills on the succeeding machine.

Packing Platform

After final inspection, the resistor moves on to a packing platform (Fig. 7) where it is pushed into a bank between two loading jaws. When the bank fills, an anvil pushes the prepositioned resistors into a Styrofoam block. The block goes down a hopper into a loading magazine.

This machine is also controlled by the computer, which actuates servo units to control the platen and anvil stroke settings for each of the four resistor sizes. The complete resistor is now ready to begin the most important phase of its life cycle—reliable service in an electronic circuit. In missile and similar electronic systems, such deposited carbon resistors are required by the millions and must work under extreme conditions of cold, heat, humidity, vibration and shock. In certain defence equipment, a failure rate of no more than one per 200 million hours of operation is permissible. It is mainly this reliability requirement which justified the design and development of the machines described. Until now, individual, precision products have been made by manual or semi-automatic processes that invited contamination from handling and related shortcomings of human control. By adopting advanced automation, contamination disappears as a problem, production is vastly increased and, most vital, a level of reliability is attained that manual methods cannot match.

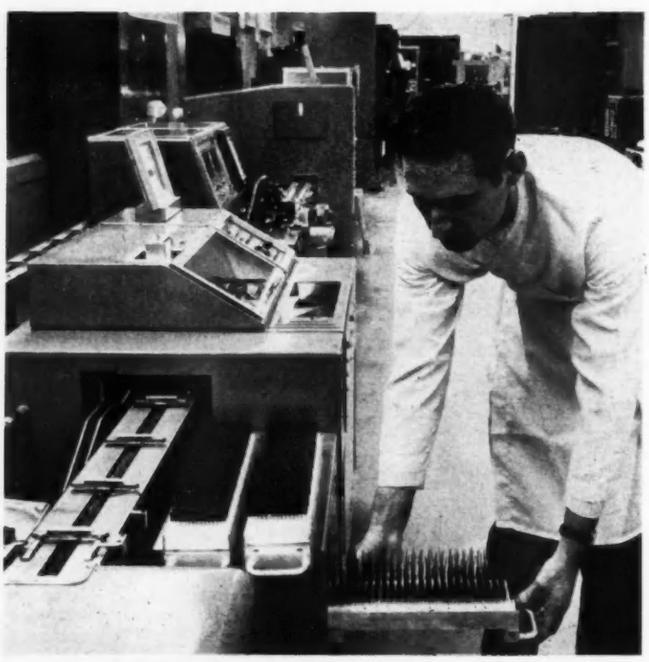


Fig. 7—Packing platform filling completed resistors into Styrofoam blocks

Computer Programmes for Highway Engineering

Thirty-seven out of fifty states in the U.S.A. are using I.B.M. computers for highway design and construction. Computer programmes covering this work have been extended this year, and have been written for the I.B.M. 1620 smaller size computer as well as for larger systems. These programmes are held in the library of I.B.M United Kingdom, Ltd, or through the H E E P organisation (Highway Engineers' Exchange of Programmes) at I.B.M., 590, Madison Avenue, New York 22.

Programmes include those written for "An Analysis of Equipment Costs"; "Sufficiency Rating (evaluating structural adequacy, service and safety)"; "Earthwork Quantities"; "Digital Terrain Model System Horizontal Alignment"; "Reduction of Triaxial Test Data"; "Density of Granular Materials"; "Bridge Design"; "Forecasting Interzonal Traffic Movements"; "Traverse Computation"; "Bearing from 'Polaris'"; "Traffic Assignment"; "Speed Check Analysis."

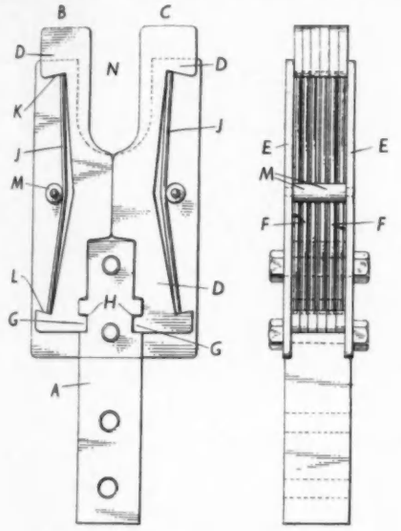
BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

ELECTRICAL ENGINEERING

869,810. December 13, 1958.—ELECTRICAL CONNECTING DEVICES, Brookhirst Switchgear, Ltd., Northgate Works, Chester. (*Inventor : Douglas Burton Robinson.*)

This invention is particularly concerned with plug contacts used, for example, in swing-out or draw-out switchgear for connecting the switchgear proper to busbars. Generally each connecting device or plug-contact will comprise two laminated fingers and where the device takes the form of a clip to embrace and grip a conductor (e.g. a busbar), the fingers will be urged towards each other by resilient struts or rods. The action of forcing the plug or clip on to the conductor or busbar, against this resiliency ensures good contact pressure and at the same time each lamination can accommodate itself independently to make the best possible contact with the conductor. In the example shown in the drawing the plug-contact comprises a body part or plug block *A* and two fingers *B* and *C*. Each finger comprises laminations *D* slidably supported one upon another and located between cheek plates *E* bolted to the plug block. If



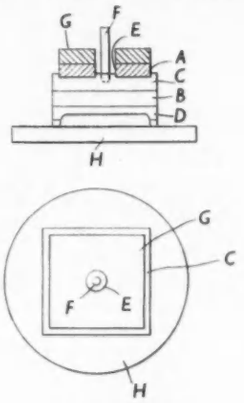
No. 869,810

the cheek plates are of metal they are insulated from the laminations as indicated at *F* in the right-hand drawing. The laminations have heel parts *G* so that they can pivot independently, at least to a limited extent, in recesses *H* provided in opposite sides of the plug block. Associated with each lamination is a resilient strut or spring rod *J* which is trapped or sprung between lugs *K* and *L* at opposite ends of the lamination and bears against an insulated abutment *M* (e.g. a pin fitted with a sleeve of insulating material) secured between the cheek plates. The arrangement is such that the resilient struts are flexed or stressed to a slight extent as shown in the left-hand drawing, whereby the laminations of the fingers are urged together to restrict a gap *N* between their fore ends. In using the plug-contact the gap *N* receives a bare busbar or other conductor as a forced fit, the laminations giving to some extent against the action of the spring struts and accommodating themselves independently to the busbar so as to obtain the best possible surface contact. The spring struts could be arranged alternatively to act outwardly on the laminations so as to form a plug adapted to plug into a socket.—*June* 7, 1961.

ELECTRONICS

869,680. March 26, 1959.—SEMICONDUCTOR DEVICES, Associated Electrical Industries, Ltd., 33, Grosvenor Place, London, S.W.1. (*Inventor : Peter Arthur Turner.*)

This invention is particularly concerned with an improved construction for a pnpn switching device or controlled rectifier. Such devices for high-speed switching of high currents by means of currents of considerably lower magnitude are arranged so that when positive and negative potentials are applied to the outer p type and n type layers, only a very small inverse current flows across the centre pn junction, but if the avalanche voltage for that junction is exceeded the current multiplication factors of the inner n and p layers increase until their sum is unity, whereupon the device offers a very low impedance to the passage of current from the outer p layer to the corresponding n layer. In practice it is inconvenient to effect switching of high currents by exceeding the avalanche voltage of the centre pn junction and it is therefore common practice to connect a trigger electrode to the inner p layer of the device so that with positive and negative potentials applied respectively to the outer p and n layers an avalanche can be initiated in the device by a pulse of current flowing



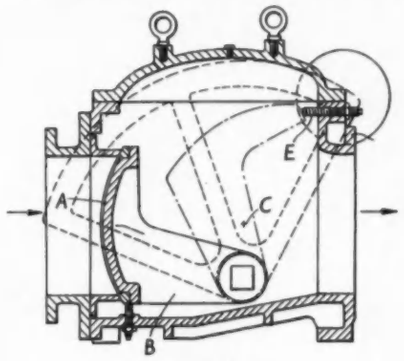
No. 869,680

from the trigger electrode to the outer n layer. The construction described in the specification has an apertured outer n layer through which the trigger is connected to the adjacent p layer so as to be substantially equidistant from all points on the adjacent boundry of the pn junction. In the drawing, n and p layers of silicon and germanium are indicated at *A* and *B* and *C* and *D* respectively. These layers are of rectangular form preferably having square major surfaces. The outermost n layer *A* has a centrally disposed circular aperture *E* extending through it which provides access to the top major surface of the p layer *C* immediately below layer *A*. Trigger electrode *F* extends through the aperture and is secured to the p layer at a position equidistant from the boundary of the pn junction between the layers *A* and *C*. One terminal member *G*, similarly shaped to the layer *A*, is bonded to the latter with its aperture in registration with the aperture *E* while another terminal member *H* of disc form is secured to the base of the device adjacent the n layer *D*. The construction according to the invention enables an avalanche to be initiated simultaneously at all points of the pn junction boundary in response to the application of a suitable triggering pulse to the trigger electrode and provides the following advantages over pnpn switching devices hitherto employed : (1) a more consistent trigger current value is obtained ; (2) a reduced voltage drop between the trigger electrode and the outer n type layer ; (3) higher speed switching can be achieved. These advantages are obtained without any great reduction in the total area of the pn junction between the outer n layer and the adjacent p layer, since the transverse cross-sectional area of the aperture through which the trigger electrode extends is small compared with the total area of contact between the two layers defining the junction.—*June* 7, 1961.

VALVES

870,804. July 30, 1959.—VALVES FOR THE CONTROL OF FLUIDS, Gwynnes Pumps Ltd., and George Andrew Wauchope, both of Wellington Foundry, Lincoln.

This invention concerns particularly hydraulic non-return valves. An ordinary non-return valve of the flap type as fitted into pipe lines to prevent return flow when a pump is closed down (especially where a large quantity is delivered against a substantial head) is unsatisfactory. It commences to close relatively slowly when pumping ceases, so that a return flow involving high velocities and very large kinetic energies may already have developed by the time that the valve is about to complete its closure. As a result, the valve closes under excessive forces and with considerable shock. Furthermore, the return flow developed is finally cut off relatively suddenly, so that surge phenomena are liable to be produced in the pipe line with resultant serious danger to equipment. The invention seeks to avoid these difficulties without the necessity for elaborate or expensive external control means. Referring to the drawing the valve member *A* is of part-cylindrical shape presenting its convex face in the upstream direction, i.e towards the pump (not shown). It is supported in the housing by two lateral arms *B* mounted on trunnions projecting through the side walls of the housing. In the fully closed position of the valve member, its axis of curvature *C* is located above the axis of the trunnions. On opening of the valve member, the axis *C* moves in a downstream direction from this position. When the valve member rocks towards the open position, it not only moves up transversely off its seating, but also recedes from the seating as the axis *C* of curvature moves in the downstream direction about the trunnion axis. The housing has an upward extension to accommodate the valve member in the fully open position (indicated in chain lines) the movement of which is arrested by a screw stop *E*. At their free ends, outside the housing, the trunnions carry arms which can be used for the application of control media such as counter-weights, hydraulic dashpots



No. 870,804

or motors. If the valve is closed, there will, normally, be water under a static head on the downstream side and no water or a reduced pressure on the upstream side. Under these conditions, the resultant of the pressure acting on the concave face of the valve member will be a force directed radially on the face face and producing, with the lever arm represented by the distance between the axes of rocking and curvature, a moment which keeps the valve tightly closed. When the pump is started up and the oppositely directed resultant force on the convex upstream face of the valve member exceeds that on the downstream face, the moment in the opposite sense will cause the valve member to rock on its trunnions in the opening direction. Even in the fully open position of the valve, there will be some excess of pressure on the upstream face and the resultant moment will hold the valve member open. When the pump is closed down, there will at once be an excess of pressure on the downstream face and reversal of the moment will cause the valve to commence to close. Closure, however, takes place steadily and without sudden slamming.—*June* 21, 1961.

RAILWAY SIGNALLING

869,896. January 14, 1957.—RAILWAY REMOTE CONTROL SYSTEMS, Associated Electrical Industries, Ltd., 33, Grosvenor Place, London, S.W.1. (*Inventors : Edwin Theodore Leighton Hare and Arthur Randall Hardman.*)

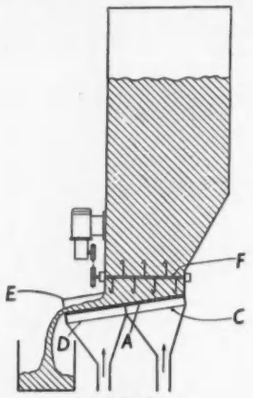
This invention relates to railway remote control systems of the kind, such as so-called centralised traffic control systems, in which the settings of signals, track points and so on, can be remotely controlled by coded electrical signals transmitted from a control point, provision usually also being made for return transmission to the control point of electrical signals coded to indicate the existing settings of the controlled field equipment. It is proposed to generate the coded signals for controls and indications by means of oscillators including, for each output frequency, a frequency-sensitive feedback coupling device comprising primary and secondary tuned reed, fork or other vibratory members. The receivers would include similar frequency-reactive devices for each frequency, the secondary members generating by their vibration an

output signal for control or indication of the device relevant to the frequency. The sharp tuning obtained with vibratory members makes the receiving means highly selective and affords high stability of the oscillating means. Consequently the signalling frequencies can lie in a lower range and be closer together than would otherwise be necessary to ensure discrimination from each other, and from other alternating currents, such as traction currents of an a.c. system. Moreover, although a primary reed or tuning fork may be forced into vibration at a frequency other than its natural frequency, negligible energy would be transferred to the secondary reed or fork, and no significant output would be obtained. A further advantage of the coupling system employed is that there is complete electrical isolation between its input and output sides, which is most desirable where, as in the case of a.c. traction systems, there is a possibility of high (traction) voltages appearing at the input side.—*June* 7, 1961.

MATERIALS HANDLING

869,981. May 4, 1959.—DEVICES FOR DISCHARGING MATERIAL FROM A CONTAINER OR SILO, Verwaltungsgesellschaft der Werkzeugmaschinenfabrik Oerlikon, Birchstrasse 155, Zurich-Oerlikon (Switzerland).

In the accompanying drawing an embodiment of the discharge device is illustrated by way of example. The silo is closed at the bottom by an inclined plate *A*, an extension of which forms the discharge chute. This may be an air permeable plate, a supporting grid or a sieve. Under the plate are air chambers *C* and *D*. Chamber *C* is located under the column of material, and the chamber *D* below the discharge chute *E*, the partition of these two chambers being



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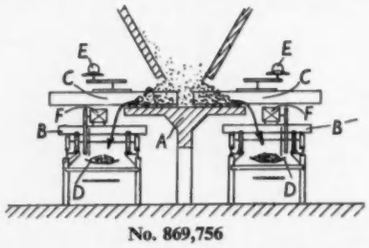
arranged upstream of the discharge opening of the silo. These chambers are connected to air pipes through each of which a regulable air stream is introduced. The air flows through the porous plate to loosen the material and carry it along, so that it flows off through the chute. The use of two air currents of different stengths allows the material to be carried off from the column and subsequently to flow off quietly through the chute. In order to prevent the formation of bridges in the material, loosening devices are arranged above the plate such as a motor-driven shaft *F* having conveyor prongs which loosen the material and convey it towards the discharge chute.—*June* 7, 1961.

869,756. November 21, 1957.—BUNKER DISCHARGE APPARATUS, Maschinenfabrik Buckau R. Wolf Aktiengesellschaft, Grevenbroich, Germany.

This invention relates to apparatus for discharging bunkers containing bulk material which tends to become jammed and form bridges in the region of the



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discharge aperture. The bunker side walls, inclined at the angle of repose of the bulk material, are spaced apart at their bottom edges to form a longitudinal aperture sufficiently wide that the material cannot jam and bridge. Below the aperture is a delivery table *A* of a width such that the material, which piles up at its natural angle of repose, cannot of itself slide over the table edges. At both sides of and below the table are rails on which run trollies *B* carrying scraper tools *C* which engage over the upper surface of the table and, in the embodiment illustrated, are in the form of scoop wheels rotated by motors and gearing *E*. The trollies have gates which open above conveyor belts *D* between the rails and through which the material is funnelled. The trolley driving motors *F* are driven synchronously. The material which piles up on the table is removed simultaneously at both sides over the whole width of the table and bridging between the edges of the bunker walls and the delivery table is prevented. The rate of delivery can be adjusted by varying the speed of the trollies and/or the speed of the scoop wheels.—*June* 7, 1961.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

WHITE METAL BEARING ALLOY INGOTS

No. 3332 : 1961. Price 5s. Requirements for nine recommended alloys—which are considered to cover the range of properties generally needed in white metal bearing alloys—are laid down in this new Standard. Although elements such as cadmium, nickel, silver, tellurium or arsenic are sometimes added to these alloys such variants have not been included in the standard because, while for particular applications improved properties are claimed, some of the resulting alloys are more difficult to use.

GALVANISED COATINGS ON WIRE

No. 443 : 1961. Price 6s. In the revised, simplified edition of this specification—which lays down requirements and tests for weight, uniformity and adhesion of zinc coating—the size range for galvanised wire has been extended : the maximum diameter is now 0·400in and the minimum, 0·009in. It also introduces the volumetric method as an alternative to the gravimetric method for determining the weight of zinc coating where the nominal diameter of the coated wire is not more than 0·195in. This method is quicker than the gravimetric, but the latter is to be used as the referee method in case of dispute.

The copper sulphate (Preece) dip method for determining the uniformity of coating is still given, but the standard no longer requires the wire to be bent round a mandrel before the dip test.

INDUSTRIAL RUBBER BOOTS

No. 3299 : 1960. Price 4s. 6d. Primarily at the request of Government departments, the British Standards Institution has published a new British Standard for industrial rubber boots. It applies to rubber boots for general purposes and does not cover boots giving protection against electrical shock or boots having antistatic or conductive properties. A companion document to B.S. 1870, Part 2 (which covers safety boots, of similar construction, which have steel toecaps), the specification gives details of the materials to be used and methods of test, to ensure a satisfacotry article. Boots said to comply with the standard must be marked B.S. 3299 : 1960 and the B.S.I. Kitemark may also be used, under licence, once the Institution is satisfied that the boots are indeed up to standard.

WROUGHT HIGH-TENSILE BRASS RODS AND SECTIONS (OTHER THAN FORGING STOCK) AND HIGH-TENSILE BRASS FORGING STOCK AND FORGINGS

No. 250 and No. 1001. Price 5s. each. In preparing the British Standard schedules for wrought copper and copper alloys (B.S. 2871–2875) an attempt has been made to rationalise the specifications for high-tensile brass and in line with this the two publications B.S. 250 and B.S. 1001 have been revised.

High-tensile properties of rods are obtained either by alloying, or up to a certain size by cold working, or by a combination of both, and materials of these types have traditionally been supplied. The 1940 edition of B.S 250 was drafted to permit the use of a number of alloys containing up to 7 per cent of alloying elements which would give the desired properties. The revised edition of the specification includes two compositions, both of which are identical with alloys being included in the series of schedules for wrought copper and copper alloys, and the designations used are identical with those in the schedules. CZ 114 is a general purpose alloy which is more closely defined than that specified in the earlier edition of the standard and will meet most engineering requirements. CZ 122 has superior machining properties, is of the same composition as that specified in B.S. 218, "Brass bars and sections (suitable for forgings) and drop forgings," and the required mechanical properties are obtainable by cold work. Except for CZ 114 in sizes 3in to 6in, the high mechanical properties will not be retained if the materials are heated and they are therefore intended for machining and general purposes only and not for forging.

The new edition of B.S. 1001 specifies a medium-strength alloy designated CZ 115 which is specially suitable for use where the material has to be soldered. This alloy, together with CZ 114 and a third high-tensile brass CZ 116, is also included in the schedule of forging stock and forgings (B.S. 2872, "Copper and copper alloys : forging stock and forgings") which will shortly be published. B.S. 1002 has been withdrawn. The same three high-tensile brasses are also included, with appropriate mechanical properties, in the schedule of rods and sections (B.S. 2874, "Copper and copper alloys : rods and sections other than forging stock") which will also be published soon.

STEEL SHEETS FOR MAGNETIC CIRCUITS OF POWER ELECTRICAL APPARATUS : PART 2 : ORIENTED STEEL

No. 601 : Part 2 : 1961. Price 5s. Unlike the earlier edition of B.S. 601, published in 1935, the new edition is in two parts. Part 1, covering non-oriented steel, was published in 1959. Part 2 has now been published. It covers oriented magnetic steel strip and sheets intended primarily for machines and transformers operating at power frequencies, and applies to material which will be supplied in one nominal thickness only and in four grades. The specification deals with material coated on both sides with a suitable insulation capable of withstanding stress-relief annealing under conditions approved by the manufacturer. Tests are laid down for total losses and a.c. excitation, effect of ageing, stacking factor and insulation values. Test procedure and formulae and typical values are included in the five appendices.

METHOD FOR THE DETERMINATION OF VAPOUR PRESSURE OF LIQUEFIED PETROLEUM GASES

No. 3324 : 1961. Price 5s. This specifies a method for the determination of the gauge vapour pressure of liquefied petroleum gas products such as propane and butane and is technically identical with I.P. 161/59T. The method is primarily intended for use with samples which have vapour pressures not exceeding 300 lb per square inch gauge at the temperature of the test, but a modified version of the apparatus for use at higher pressures is included. Two variants of the method are described, differing in the temperature of the test. Method A is for tests at 100 deg. Fah. (37·8 deg. Cent.) and is applicable to samples of commercial propane and butane. Method B is for temperatures up to 149 deg. Fah. (65 deg. Cent.).

METHOD FOR THE DETERMINATION OF REID VAPOUR PRESSURE OF PETROLEUM PRODUCTS

No. 3325 : 1961. Price 5s. The method specified is suitable for determining the absolute vapour pressure of volatile, non-viscous petroleum products, except liquefied petroleum gases, for which it gives low results. In a modified form it can be applied to blends containing alcohols or other water soluble materials. It is technically identical with I.P. 69/60. Apparatus and procedure are specified in detail. In the calculation of the result it is necessary to apply certain corrections and instructions for evaluating these are included.

Forthcoming Engagements

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Wed., Aug. 2.—MANCHESTER BRANCH : Engineers' Club, Albert Square, Manchester, Films Evening, 7.15 p.m.

Advanced Engineering Courses

Techniques of Non-Destructive Testing. PHYSICS DEPARTMENT, BRUNELL COLLEGE OF TECHNOLOGY, Woodlands Avenue, Acton, London, W.3. An evening course of eleven lectures, every Wednesday from 7 p.m. to 8.30 p.m., commencing Wednesday, October 4, 1961. The lectures will be on topics such as radiology, ultrasonics, eddy currents, magnetic methods and thermal conductivity. Fee £1.

Metal Cutting Principles. THE UNIVERSITY OF BIRMINGHAM, Institute for Engineering Production, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham, 15. A two-week course, planned by Professor Milton C. Shaw, head of the Metals Processing Division of the Massachusetts Institute of Technology, U.S.A., intended for senior production engineers. The course runs from August 21 to September 1, 1961. Fee 70 guineas, covering all residential charges and meals.

Corrosion Problems in the Electrical Power Industry. ELECTRICITY CORROSION SUMMER SCHOOL, Battersea College of Technology, London, S.W.11. For the first time, the Corrosion Summer School is concerned with the particular aspects of corrosion met in one industry. Starting with boiler feedwater, corrosion and its prevention are surveyed as they affect each stage of generation, concluding with transmission and distribution. The course is being held from September 25 to 28. It is hoped to arrange a visit to Central Electricity Research Laboratories, Leatherhead, on Thursday, September 28. Fee £10.

The Principles of Rotodynamic Machines. BOROUGH POLYTECHNIC, Borough Road, London, S.E.1. A course of thirteen lectures to be given on Tuesday evenings, commencing September 26, 1961, at 6.30 p.m. The course will be concerned with the principles of certain hydraulic turbines and rotodynamic pumps. It is intended for students who have previously qualified in mechanics of fluids to Higher National Certificate standard, or who hold another suitable qualification. Fee £6.